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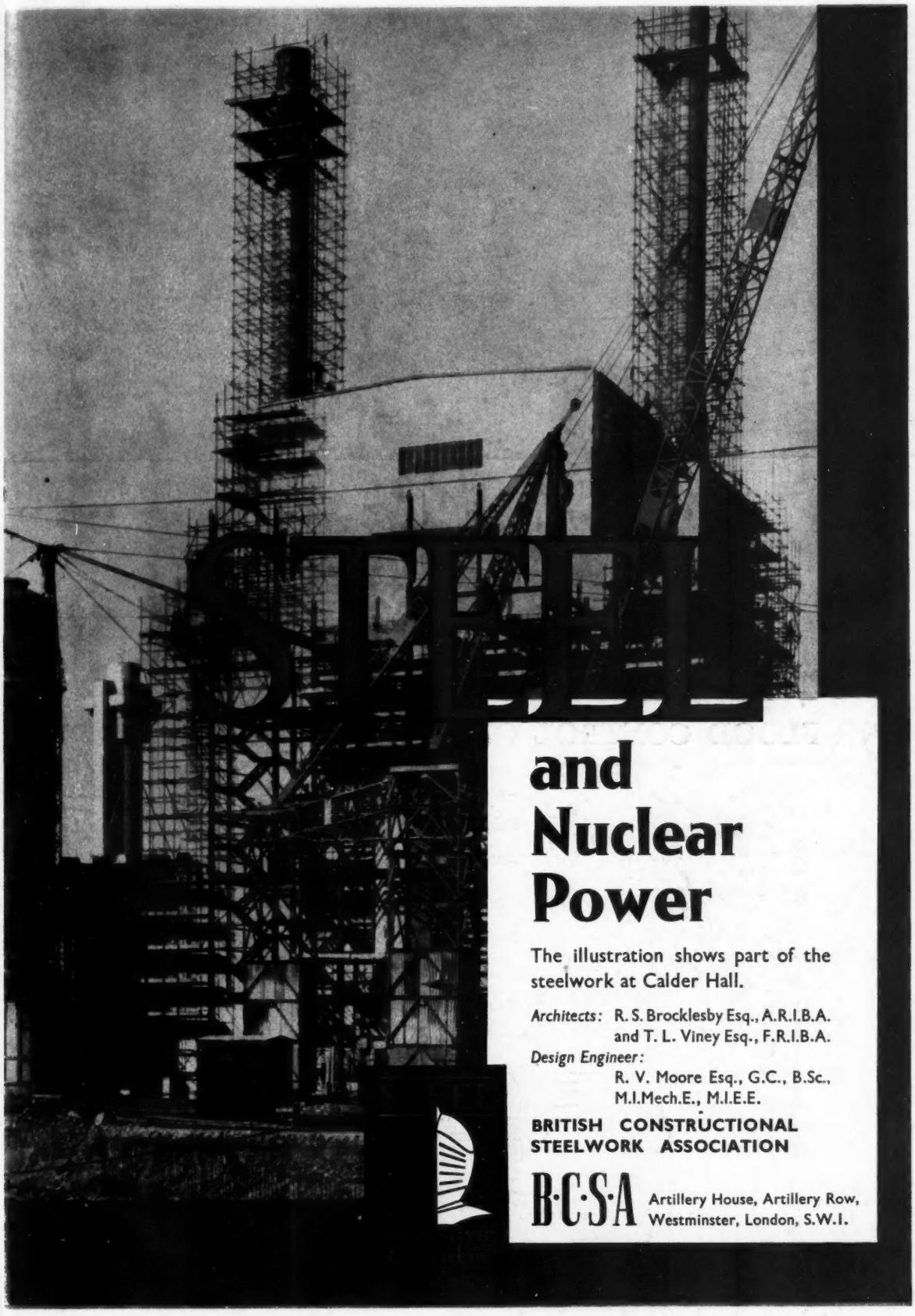

and Nuclear Power

The illustration shows part of the steelwork at Calder Hall.

Architects: R. S. Brocklesby Esq., A.R.I.B.A. and T. L. Viney Esq., F.R.I.B.A.

Design Engineer: R. V. Moore Esq., G.C., B.Sc., M.I.Mech.E., M.I.E.E.

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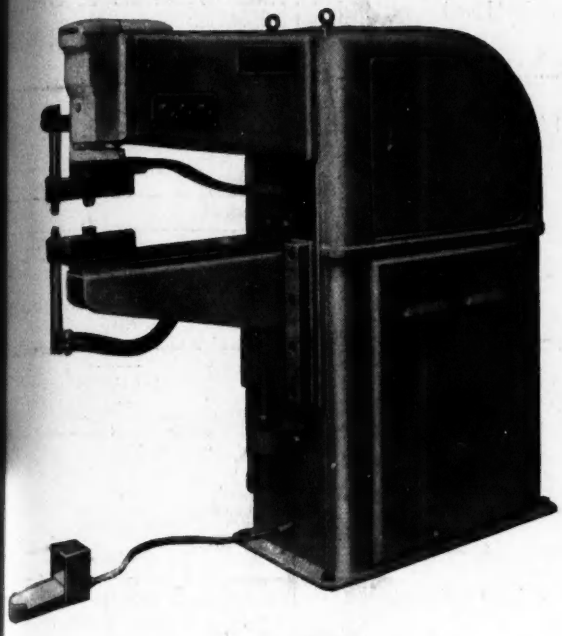

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ESTABLISHED 1856

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E975

THE ENGINEER

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ACCIDENT AT WINDSCALE

Full responsibility has been accepted by the U.K. Atomic Energy Authority for the recent accident at Windscale. The committee of inquiry found that the cause lay partly in inadequacies of instrumentation (at least with respect to the kind of routine maintenance that was being carried out at the time), and partly in the operators' faults of judgment. The faults of judgment are attributed to weaknesses of organisation, and no blame is attached to any individual. What blame there is, if blame is indeed to be placed, the Authority wishes to bear collectively. There is a fine air of honesty about the White Paper on the accident, and this predisposes one to accept it without criticism. The candid admission of flaws in the organisation, the frank acknowledgment of the delay that occurred between the recognition of the danger and the setting up of a suitable sampling programme, and the courageous refusal to name a scapegoat of any kind, all tend to disarm attack. Undoubtedly, too, the devotion to duty and the prompt and efficient action of the Windscale staff (which are properly recognised in the White Paper) all played their part in reducing the harmful consequences of the accident.

Perhaps, indeed there is no severe criticism that can be fairly made. The pile concerned was the simplest in conception that could have been built to meet its particular purpose—the prompt production of plutonium for military use. It was erected at a time when Wigner energy was known about, but when methods of dealing with it were not clearly understood. Experience soon showed what was to be done, and an annealing procedure became part of the established routine. However, no special section on this procedure was inserted in the Pile Operating Manual, and the instrumentation was not revised to give all possible guidance to the staff during the process. This is all very understandable. The operation of what was perhaps a fairly risky military plant from the beginning evolved and changed subtly as the inevitable and unforeseeable lessons were learned about it. But such a form of argument is rather too dangerous a luxury. Complacency is a fatal attitude to allow when dealing with new processes that have not yet completely won the confidence of all who are involved. The White Paper is marred by a certain underplaying of the delay caused when the scanning gear jammed and failed to perform its task. This had happened on previous occasions, and the omission to rectify the fault cannot be ignored. Contempt, or at least a certain neglect, appears to have been bred of the operators' familiarity with their charge. It is good to know that independent committees have been set up under Sir Alexander Fleck to recommend remedies. Another mild blemish in the White Paper is the undue secrecy within which some of the operating details have been shrouded.

The Authority's reassurances on the immunity of Calder Hall reactors from accidents of the Windscale variety will, we feel sure, be accepted by the majority of people. What appear to be sound and sensible reasons are given in an annex to the White Paper for believing that such spreading of radioactive material about the countryside is almost impossible and local overheating unlikely. The dangers from the use of air as a coolant are avoided at Calder Hall and the Electricity Authority's reactors, since there the medium is carbon dioxide. Furthermore, the gas is circulated in a closed system, and leakage is negligibly small. The monitoring of the fuel element channels is not done by moving a scanner over the face of these power reactors, but by means of stationary detectors. Cartridge design has been improved, making a burst less likely, and control instrumentation systems have become more advanced in the years since Windscale was built. Nevertheless, we doubt whether in so large an object as a reactor it is possible to be sure that the highest temperatures reached are always recorded, more particularly when some other operation than the routine generation of power is being performed. Furthermore, Calder Hall power station, though used for the supply of power to the Grid, is, after all, a prototype, from which the engineers of the Atomic Energy Authority hope to learn ; we have no doubt that it is not always run in routine fashion but that certain experiments are performed from time to time to elucidate problems in the operation of such a reactor which may have their bearing upon the design and operation of larger reactors. In these circumstances the possibility that there might be local over-heating at Calder Hall if there were an insufficient level of skill or judgment amongst its staff cannot be wholly ruled out. Any accident there, even though it occurred whilst an experiment was being

performed, and even though there were no danger of spreading radioactive material around, might have serious repercussions on the nuclear power programme and export prospects. But providing the Atomic Energy Authority—and industrial firms !—have learnt the right lessons from the accident at Windscale, as we think they have and will, there need be no need for disquiet, and no need to fear that the nuclear power programme will suffer. As is so often the experience of engineers, an accident will have contributed materially to better understanding of a technical problem.

SCIENTISTS AND DEFENCE CUTS

The Advisory Council on Scientific Policy in its annual report for 1956–57 has done well to draw attention to a particular possible consequence of the defence cuts recently announced by the Government. For of the total number of scientists and engineers employed on research and development in this country in 1955–56, not far short of one-half were employed in defence work either in Government establishments or within industry. What will happen to those men if the work of Government research establishments is reduced and fewer research and development contracts are entered into with industry ? There is, of course, within certain industries, a shortage of highly qualified men ; and those industries will welcome an opportunity to replenish their research staffs from the staffs of defence establishments. In addition, in certain industries that have benefited, for civilian purposes, from conducting defence researches on behalf of the Government—the aeronautical, electronics and nuclear power industries spring to mind—it may well be that a substantial proportion of the men released by defence cuts will be merely transferred to civilian research. Nevertheless, the council foresees a possibility that " unless efforts are made to assist highly qualified men to find new jobs which they will regard as satisfactory, there may be an increase in emigration in particular to the United States and Canada, where there is a large unsatisfied demand for such men." The council therefore suggests that the use of Govermental civil research and development contracts should be re-examined ; and it clearly hopes that industry will be able to suggest suitable subjects. But for our part we remain doubtful. Active and advanced industries in this country already undertake much research for themselves and fully support their research associations. They are likely to prefer to keep control in their own hands rather than suggest subjects for Government financed research. The field open for Government financed research for civilian purposes surely lies in the stimulation of more backward industries, industries unlikely to be sufficiently interested to suggest subjects for themselves. In fact, we suggest that the Advisory Council itself might give consideration to this matter so as to have in mind suitable subjects should there prove to be evidence of an undue loss of able men from this country in consequence of the defence cuts. Having read that remarkable survey *Industry and Technical Progress*, we conclude that certain industries are neither very likely to " lift themselves by their own boot-straps " towards the use of advanced methods nor particularly alive to any need to do so. Stimulation by Government sponsored civilian research might do the trick.

EDMONTON AND ENGINEERS

Back in 1951, the Edmonton Borough Council made it a condition of employment when advertising a vacancy for a borough engineer and surveyor that " the person appointed shall during the term of his employment by the borough council be and continue to be a member of a trade union affiliated to or specified by the Trades Union Congress as eligible for affiliation to the T.U.C." Earlier the Durham County Council in an affair that attracted nation-wide attention had attempted to impose a similar condition of employment upon teachers ; but the teachers, being a well-organised body, were able to defeat this attempt to dictate to them upon a matter closely affecting their professional freedom. That council was forced to withdraw the offending rule under instruction from the Minister of Education. But in 1952 the same council made an attempt to apply a similar rule to other professions. It led to the formation of a Joint Emergency Committee of the Professions, including the Engineers' Guild, and that committee was eventually successful in resisting the council, which withdrew the offending rules. At Edmonton, however, the history was different. The matter was immediately taken up in 1951 by the Engineers' Guild in conjunction with the Association of Local Government Officers and Surveyors. A question asked in the House of Commons elicited the reply from the Minister of Transport that if the borough council insisted upon its condition there could be no grant from the Road Fund in respect of the salary of the borough engineer and surveyor since the condition offended against the established principle that councils should make their choice from as wide as possible a field of candidates. The borough council gave way. It is now clear, however, that it gave way without abandoning its hope of imposing its " closed shop " ideas at some other time.

Now the issue has been raised again ; and its form is similar to that in which it was raised at Durham. Edmonton Borough Council has imposed as a condition of employment of all except doctors, nurses, dentists, health visitors and midwives that they shall be members of trade unions, that is, professional engineers—and, presumably, other professional men —employed by the borough council must become members of trade unions. The rule does not apply, however, to the borough surveyor. The council of the Engineers' Guild has forthrightly stated that it " considers such a requirement inconsistent with the professional standing of the persons concerned, irrelevant to their capacity to carry out their professional duties and a serious interference with the freedom of the individual." The requirement amounts in our view to a serious misunderstanding by the borough council of the attachment of all professional men, not professional engineers alone, to the principle of free association—that is, to the freedom to associate or not to associate according to individual approval or disapproval of the objects of an association and its methods ; or, alternatively, to a serious under-valuation of the status of professional engineers and other professional people. We applaud, therefore, the determination of the Guild to resist the decision of the Edmonton Borough Council " by every means at its disposal." As a condition of employment the requirement is obnoxious and offensive. It is opposed not only to the interests of professional engineers, but to those of Edmonton itself since it limits the borough council's choice in appointing engineers. We hope the Guild will push its resistance with vigour and that it will receive support from other professions that may be affected, in principle, or because they have members holding posts under the council.

" UNIVERSAL " BEAMS AND COLUMNS

The new rolling mill at Lackenby for structural components which Dorman Long and Co., Ltd., plans to bring into production next spring, will make a significant contribution to the country's economy. The new mill will achieve an increase of about 20 per cent in the national production of structural steel and for the first time a complete range of broad-flange beams and columns will be available to the structural engineer. Sections of this kind have been available for many years in the United States, and from one mill on the Continent (even though the rolling process used was devised by an Englishman) and a limited range of broad-flange beams have been available in this country. The complete answer to this problem, however, required the construction of a new mill, which has now been practically achieved.

The conventional British Standard sections are limited in size and in the distribution of material across the section by the method of rolling. Generally, a rectangular bloom is passed through grooves between two-high or three-high

mills, the grooves being shaped to produce the familiar I-section. Plenty of flange taper is needed, so that the flanges will not stick in the grooves. The flange width is restricted, because the velocity of the face of the roll varies ; the I-section is disposed horizontally between the two horizontal axes of rotations of the rolls, so the velocity of the roll surface is less at the tips of the flanges than at the web ; further, the flanges do not receive proper rolling pressure. These factors limit the product in size and shape as we have already explained. The more elaborate system which will be used to roll the so-called " universal " sections at Lackenby is explained in the abstract from Messrs. Barlow and Foster's paper before the Institution of Structural Engineers, which we reproduced on page 673 last week. The range of sizes and properties of the new sections are indicated briefly in the paper. It is considered that they approach the ultimate efficiency which can be obtained simply by virtue of cross-sectional distribution of material, and also that they will supersede the British Standard sections in a great deal of work. Trial designs have shown 5 to 10 per cent weight saving, between the two, but, more important still, substantial saving in fabricating costs and thus in the time needed in manufacture.

The new mill is of special interest, also, on account of the popularity of prestressed and reinforced concrete, which, together, are the chief material competing with structural steel. It is now generally conceded that, in London at least, reinforced concrete frames are cheaper than structural steel ones for the commonest range of heights for buildings. The " universal " sections will help to restore the balance, and represent the steelmakers' contribution—evidently his " ultimate " one in mild steel—to greater economy. Further improvement will have to come from better design—probably by developments in the use of plastic theory—but, more important still, by a modified approach to fire protection. The encasement of steel in concrete for this purpose is a drawback, structurally ; there are three possibilities of improvement (*a*) by abating the regulations for fire protection of steel ; (*b*) by employing composite design to the full, as suggested by recent work by the late Dr. Faber and by the Building Research Station, and (*c*) by finding some new, non-structural insulating material, to protect the steel. It will be interesting to see whether any such developments will emerge in the near future to reinforce the advantages of the " universal " sections and place structural steel in a really competitive position. Doubtless such a situation would encourage further advances in methods of using structural concrete, which is just the situation that, having no stake in either industry, we like to see.

A Seven Day Journal

" Neptune " Zero-Energy Reactor Goes Critical

" NEPTUNE," a zero-energy nuclear reactor built at the U.K. Atomic Energy Research Establishment, Harwell, went critical for the first time on November 7. It may be recalled that " Neptune " will be used to study in detail the behaviour of neutrons in water-moderated core designs, with specific reference to a pressurised water reactor for submarine propulsion. The reactor will be used to check the design calculations for the land-based prototype submarine reactor, for which civil engineering work has begun at the Authority's establishment at Dounreay. Work on " Neptune " will be done by Admiralty staff at Harwell in association with Authority staff. In " Neptune" enriched uranium is the fuel and ordinary water is the moderator ; no special cooling is required since only a few watts of heat will be generated. The reactor has been designed to allow the rapid assembly of many different kinds of cores. Its core is formed by assembling boxes of fuel element plates inside a large heavily shielded aluminium tank containing the water moderator. The water in the tank can be adjusted precisely to any required level and the water level is used as one means of regulating the reactor. Another method of control is by a neutron absorbing cadmium rod, moving vertically in or out of the reactor core. The reactor is shut off by allowing two groups of neutron absorbing plates to fall by gravity into the core, and by dumping the water at the same time into storage tanks beneath the reactor. The reactor is not pressurised, but the water can be heated to about 90 deg. Cent. to study the variations in neutron behaviour caused by increased moderator and fuel temperatures. In the design and construction of " Neptune " Rolls-Royce, Ltd., a member of Vickers Nuclear Engineering, Ltd., was responsible to the Admiralty. The Atomic Energy Research Establishment was responsible for providing detailed advice, particularly on physics, instrumentation and safety during the design and construction stages, and for supplying the reactor building, essential services and fuel. The main sub-contractors in the design and construction of the reactor itself were Elliott Bros. (London), Ltd., and Head Wrightson (Teesdale), Ltd. Twenty-three other sub-contractors also participated in the " Neptune " project.

The Engineer

100 Years Ago

(NOVEMBER 13, 1857)

" THE MONEY CRISIS "

" The most vigorous measures are being taken to meet the exigencies arising from the monetary and commercial crisis now existing. Bar gold, for example, is thrice a week forwarded in large quantities to the Mint, and thrice a week is gold coin returned from that establishment to the Bank. The coinage of gold is, in fact, going on to an extent almost without parallel, and the powerful resources of the Mint were never taxed more than at this hour. It is no unusual thing now for gold to leave the crucible in the morning and on the same evening to be deposited in the Mint safes in the form of sovereigns ! All semblance of unnecessary form has been swept away from the coining department, and nothing is permitted to impede the progress of the coinage but the inevitable processes of manipulation.

" There was a time, and that not long since, when mystification reigned paramount in the executive section of the Royal Mint, and when delays and difficulties of the most ' frivolous and vexatious ' character frequently arose, or were created. It is not so now ; barriers which seemed to have been raised for the express purpose of creating confusion, and of stopping the course of public business, have been got rid of, and red tape has become a thing of the past. Fortunate is it that these reforms have been introduced, for, in such exciting and exceptional times as the present, it is indeed essential that free action be permitted to the machinery, literal and figurative, of that great establishment. In the hands of theorists and others who, instead of governing and directing the artificers and workmen, were governed and directed by them, the Mint might have continued to be an inefficient minister to the wants of the times. Under the management of practical men, who are not afraid and not incapable of putting, if need be, their own hands to the work in progress, it is, however, a promoter of the general good."

Careers in Agricultural Engineering

LAST Monday afternoon, more than seventy schoolboys were present at a meeting in London at which there was given the first " careers " lecture arranged by the Institution of British Agricultural Engineers. The lecture was presented, in two parts, by Mr. J. E. Bywater, assistant chief engineer of the Ford Motor Company, Ltd., and Mr. W. H. Cashmore, director of the National Institute of Agricultural Engineering.

Mr. Bywater's portion of the lecture dealt with the training and work of agricultural engineers in industry. He submitted that engineering was not a science, but was a technology that leaned more heavily on mathematics and science than did most. From there he went on to emphasise that there was an " art content " in engineering which was often insufficiently appreciated. Before talking in some detail about training procedures and the work required in tractor and implement manufacturing establishments, Mr. Bywater commented on such matters as the need for being prepared to learn and on the importance of professional integrity. Engineering, he added, certainly provided an outlet for creative ability, and whilst each branch of engineering had its own particular attraction, agricultural engineering offered a mixture of engineering and the advantages associated with working on the land.

Mr. Cashmore's contribution dealt with the research side of agricultural engineering. He demonstrated how research and development projects such as those undertaken by the National Institute of Agricultural Engineering were directed to the task of increasing the world's food production. The lecture was illustrated throughout by short films.

Royal Aeronautical Society

THE Council of the Royal Aeronautical Society decided, during the Presidency of Mr. N. E. Rowe, to evoke the power included in its Charter of 1949 to create sections within

the society. There was announced last June the formation of the first, the Guided Flight Section, which is directed by a committee under the chairmanship of Dr. G. W. H. Gardner; the section will include astronautics in its field of activity. The first meeting will take place at the Royal Institution at 6 p.m. on November 21: Mr. J. Serby, C.B.E., B.A., F.R.Ae.S., Director-General of Guided Weapons, Ministry of Supply, will speak on "Guided Weapons and Aircraft—Some Differences in Design and Development."

Safety of Cycles

THE D.S.I.R. Road Research Laboratory has made certain investigations into the safety of pedal cycles and motor-assisted cycles which are the subject of Road Research Technical Paper No. 38 (H.M. Stationery Office, price 2s. 9d.). A sample of five motor-assisted and six pedal cycles, representing 1953–54 machines, was studied: the acceleration of the motorised cycles between 5 m.p.h. and 15 m.p.h. varied between 0·03 *g* and 0·06 *g*, and is described as about the same as a pedal cyclist pedalling hard. Braking performance was also measured: one motorised cycle with good braking in dry weather was significantly worse than a pedal cycle when wet. A rig was used to measure braking performance under laboratory conditions; it appeared that indistinguishable brake blocks could vary in the ratio 2 : 1 in dynamic coefficient of friction. The effect of stiffening the brake-shoe assembly was investigated but not reported: one of the materials is reported to have "locked" the wheel (i.e. caused a clutch in the rig to slip).

The handling qualities of the machines were investigated by simple manœuvrability tests; the behaviour of machines in which the dynamic stability is augmented or reduced by the engine is discussed at length. The report also discusses accidents to the subject machines, and observes a relatively large proportion in which the rider fell off without any apparent cause: one-third of casualties occurred in accidents involving no other vehicle.

Water Supply Improvements in Glasgow

NEW works giving a water supply to the eastern area of Glasgow—the Garthamlock works—were inaugurated on October 31. They serve an area incorporated within the city boundary in 1937, where there are now housing sites, at Garthamlock and Ruchazie, and the Easterhouse township. The new works consist of a service reservoir of 3 m.g. capacity, the first half of which has been completed; a pumping station drawing from the reservoir, and with three pumping sets installed, each able to deliver 1 m.g.d. against a head of 150ft; a water tower of 1 m.g. capacity and 132ft high; a 24in rising main supplying the service reservoir, and about 31 miles of distributing mains. The water tower is stated to be unequalled in waterworks practice for its size and height above ground level, and the eighteen circular reinforced concrete columns disposed round the periphery of the tower are stated to be exceptionally long. The tower is visible from all directions, but is considered to be a pleasing structure. Water levels in the tower and reservoir and delivery of water are all recorded on an instrument panel in the pumping station, which is fully automatic in operation. These works were designed and built under the control of the Glasgow Water Department's chief engineer, Mr. S. D. Canvin, M.I.C.E.

French Locomotive Experiences

By EDWARD H. LIVESAY

No. I—LONDON–PARIS, 1956

ONE would not deliberately choose October for a visit to France in order to observe locomotive performance from the footplate; autumn days get shorter, and with falling leaf the weather may begin to deteriorate, neither condition adding to pleasure nor profit. Notwithstanding these drawbacks, this was the only month available for a third all-too-brief excursion, and plans had to conform, including the departure time of the train from London, which, on previous occasions, had been the "Golden Arrow." Had this train been again chosen, arrangements on the other side of the Channel would have been unsatisfactory; at least half the run from Calais to Paris would have been done after dark, when, to my thinking, cab travel is to be avoided if possible; one misses a good deal of interest both inside and outside the cab, and pleasure is reduced, even though the cab may be electrically lit, as, of course, it always is on French locomotives. It was therefore decided to leave Victoria at 10 a.m., and connect with train No. 82 at Calais, reaching Paris shortly after 6 p.m., whereas the "Golden Arrow" would not have arrived until 9.30. Other reasons also made the earlier departure from London preferable, one being that the first leg of the journey would be done on a "Merchant Navy" "Pacific," instead of—as on former occasions—a "Britannia" or "Battle of Britain"; comparisons would be possible and variety is the spice of life where locomotives are concerned.

Fig. 1—Modified "Merchant Navy" class locomotive, No. 35022, "Holland-America Line"

Some of the principal dimensions of the "Merchant Navy" "Pacifics" (Fig. 1) are:

Cylinders (three)	18in × 24in
Driving wheels	6ft 2in
Heating surface:	
Tubes and flues	2,176 sq. ft
Firebox and syphon (when fitted)	275 sq. ft
Superheater	822 sq. ft
Total	3,273 sq. ft
Grate area	48·5 sq. ft
Steam pressure	280 lb (originally), reduced to 250 lb
Adhesion weight	63 tons
Engine weight	94·75 tons
Tender weight	48/53 tons, according to capacity
Coal	5 tons
Water	5000/6000 gallons
Tractive effort	37,500 lb (with 250 lb pressure, 33482 lb.)
Factor of adhesion	3·76 (with 250 lb pressure, 4·21)

There has probably been more controversy over these engines than any contemporary British designs, and though they have done, and still do, outstanding performances, it is common knowledge that some ideas, introduced with the best intentions by their talented designer, have not altogether come up to expectations. There is no need for me to thresh old straw by enlarging on these disappointments, which has been done almost *ad nauseam* already; such comments would be all the more out of order in view of the fact that rebuilding of the class is well under way, several having already been turned out with many of the debatable features eliminated. I have had the pleasure of riding on one of these reconstructed engines (No. 35022, "Holland–America Line" Fig. 1), and a real pleasure it was; I think the conversion has been admirably done, the result being in the highest degree creditable to everyone concerned. It happened that I had made a couple of runs on one of the rebuilt engines a week or so before going to France, and looked forward to comparing the two classes—the respective "before and after" behaviour—though there was little doubt what the verdict would be. More than once during the runs on the reconditioned "Pacific" I was so favourably impressed as to come out unequivocally with the remark that it was the best engine I had ridden in Britain for quite a while; there was no fault to be found with it. And there wasn't—steaming, riding, absence of slipping, all impeccable. As to appearance, granted a minor point, the improvement is immense—in my humble opinion—a very fine-looking, impressive locomotive (Fig. 1). The runs were thoroughly enjoyable—they come into the same category as those made on the S.N.C.F.! All this in passing—we are concerned here with the orthodox "Merchant Navys."

The 10 a.m. train left Victoria punctually, headed by No. 35038, "Clan Line," in charge of driver Wing and fireman Hake, of Stewarts Lane, with inspector Nanson holding a watching brief; the load was 460 tons gross, and the weather dull, dry, but threaten-

Fig. 2—Locomotive No. 231E45 with Messrs. Leseigneur and Fillon, S.N.C.F.

ing. The preliminary slipping that one rather anticipates with a Bulleid "Pacific" did not occur, nor did it on the stiff little piece of 1 in 62 approaching the river. These engines are undoubtedly rather prone to lose their foothold for reasons I prefer not to be dogmatic about; there is probably more than one—such as the factor of adhesion, 3·76, which is rather on the low side.* Up the 1 in 73 rise to Brixton the regulator was full open, the cut-off 44 per cent, and steam 235 lb—this was a 250 lb engine. Herne Hill was passed 2 min late, due to a signal check down to 10 m.p.h., but at Penge East speed had been regained, and Kent House was run through at 60, after emerging from the Sydenham tunnel on, I believe, 1 in 100 down. The riding was jotted down as "satisfactory," which means it was not quite up to Bulleid "Pacific" standard, but good enough so far; these engines have always had a good reputation in this respect, much better than some that could be mentioned, on which I have been anything but happy recently—on another line.

Not until London and suburbia are cleared can this route, the old South Eastern main line, be regarded as suitable for fast running; curvature, gradients, junctions and traffic all forbid it; when a slight drizzle sets in, as it did at Beckenham, another difficulty is added to an engineman's task. Again, a signal check, at Bickley, where we were back on time; immediately after came a restriction to 20 m.p.h. for curvature; then, at Petts Wood, the line became less sinuous, and the engine could be opened out somewhat. Gradients hereabouts are mostly rising, beginning with 1 in 234 at Shortlands, stiffening to 1 in 140, and culminating with 1 in 120 at the Knockholt summit. Then a sharp drop through Pol Hill tunnel, until just beyond the foot of the descent through Dunton Green, speeding up was evident, with 75 m.p.h. held awhile, pending a reduction on the 1 in 140 rise to Sevenoaks. Nearing Chelwood, at my request Nanson pointed out the bridge against which, some years ago, a Maunsell 2-6-4 tank engine was wrecked at speed after derailment, with serious loss of life, the result of rolling, to which the class was rather prone, intensified by defective waterlogged track. They were subsequently converted to tender engines, in which shape they still run.

At Sevenoaks, 10.38, a p.w. restriction brought us down to 10 m.p.h.; we picked up again through the long tunnel, descending, and emerging at 70, our speed was high to Tonbridge, 10.46, where there is a permanent restriction of 50; here we were again 2 min down, due to the cumulative effect of checks and the said restrictions.

Inside the cab, various things were noted. The Yorkshire coal was good, and the engine had steamed very well, pressure keeping well up; the "butterfly" firedoor was hand-operated, the treadle having been removed and the steam gear not in working order. Firemen do not seem to care much for these devices and are content to do without them, which I can only put down to force of custom, as I cannot imagine any man who once got used to them ever preferring the average awkward British firedoor, with its levers, links and toggles, often jambing with dust and grit, and calling for considerable effort to manipulate. Even without the mechanical gear, the butterfly door, hinged at the top, is far easier to work than the usual door more or less standard on other British engines, and Hake was quite satisfied with it. However, in the absence of mechanical operation, I think the inward-swinging, three-section French firedoor is the best of all, but this will come into the account in due course on the other side of the Channel.

The lay-out of cab fittings and controls is certainly good on the Bulleid engines, any cramping being due to the restricted loading gauge, and chiefly concerns height; the top of the windows, for instance, is too low for anyone but an undersized man sitting in the fireman's seat. I found from painful experience that my head had to be either right in or right out of the cab, and that transference from one position to the other was apt to be amusing—to the fireman. The look-ahead is as good as can be achieved in view of the above restriction, thanks to the backward sloping front windows. Some of these engines on which I have ridden have had speed indicators, but I forget whether this particular one had; if so, I could not have noticed it until the run was nearly over. I am strongly of the opinion that all express engines, at any rate, should have them; under many circumstances, they are invaluable, almost essential, particularly after dark when even the most experienced driver can misjudge his speed. But this, of course would call for electric light, another thing one misses on many British engines, a "convenience" almost equally essential; Bulleid "Pacifics" have it. A miserable little oil lamp cuddling up against the water gauge is an anachronism in this year of grace 1957. There, again, presumably cost and maintenance are responsible for the lack of proper illumination, coupled with shortage of shed staff to take care of electrical equipment, so I suppose nobody is to blame.

Long straights succeed Tonbridge, suitable for fast running, 75-plus being fairly frequent. Mardon was passed at 10.55, and here another drizzle set in, resulting in considerable slipping, even on the level, which I cannot account for, unless worn tyres had something to do with it. Hereabouts, my notes say: "Fireman a good lad—steaming very well—rather more slipping than necessary—riding satisfactory, but could be better." I am somewhat allergic to rough riding, having experienced quite a lot of it recently on another well-known class of express engine, which induced me to try and track it down. None of the basic causes deduced apply to the Bulleid "Pacifics," which have always impressed me very favourably in this respect. Front and rear truck and cylinder layout are different in the two classes, all three connecting-rods driving the middle axle on the Bulleids. "Clan Line's" somewhat less than perfect action may have been legitimate enough—perhaps a shopping was due, with axlebox guides or spring adjustment called for. Returning to the slipping; by chance, a week or two before, I had ridden another Bulleid over a different route, when there was really excessive loss of foothold, which went on for miles, neither wet rails nor gradient being responsible. Worn tyres again—defective sanding gear? Hardly the latter; sanding should not have been necessary under the circumstances. Nothing is more disturbing than to feel an engine begin shuddering, vibrating, knocking, and continue to do so, despite every effort of the driver to check it, with regulator and reverse, speed falling the while; one prays for equilibrium and adhesion to be re-established, wondering if they ever will be. That is an experience a sympathetic observer does not enjoy—nor a conscientious driver, either!

Staplehurst; here I tried to pick out the place where Dickens was involved in a bad derailment from which his nerves never fully recovered. He was in the only carriage that did not go over into the adjoining stream, and escaped injury, helping with praiseworthy energy in removing the dying and dead, for which good offices the company sent him a resolution of thanks. The accident left such an impression upon him that subsequently hours spent on railways were hours of dread, as they might well be to anyone of his nervous, emotional temperament. I did not consult Nanson about this, thinking he might not know, as it took place in 1865, somewhat before his time—even mine.

The speed remained high along the many straight miles succeeding Staplehurst, through Headcorn and Pluckley, one of the longest stretches without curvature in Britain, until there came a reduction to 50 m.p.h. through Ashford, and a steady rise at 1 in 266 began, leading up to the summit over the South Downs at Westenhanger. All hard work for engine and Hake was over now, only a descent for 10 miles or so through Folkestone and five tunnels remaining, with restrictions through Folkestone Junction—where we were 1 min ahead of time—and one in a tunnel for relaying, to a final stand in Dover Marine Station at 11.31, still a minute to the good; 77 miles in 91 min, 50·7 m.p.h.; a good performance, the best I have experienced over the route. No doubt better time could be done, but, in any case, the few minutes saved would not be worth achievement over such a short and difficult line. Thanks to the courtesy of Southern officialdom, a period was put to this very pleasant run by my being taken straight from the engine to the purser's office of the ship, by-passing all embarkation formalities, which was balm in Gilead, and for this my thanks are tendered to all responsible.

Epilogue.—Comparing "Clan Line" with No. 35022, "Holland-America Line," the rebuilt "Pacific"—the laurel wreath is bestowed on the latter, as forecasted.

There followed a smooth and sunny crossing to Calais, where an official of the S.N.C.F. was to meet me to simplify landing procedure, and ensure timely connection

* Slightly higher with 250 lb steam pressure.

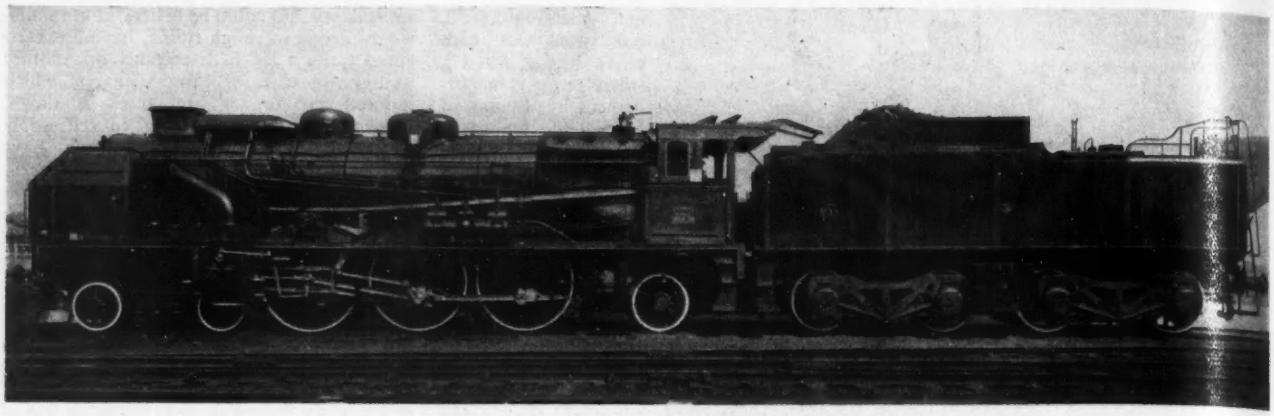


Fig. 3—"Super-Pacific," No. 231E45, S.N.C.F.

with train N.82, but his services were not required. From the deck it was seen to be standing in the station, so the obvious thing was to walk down the gangway to it without bothering anybody, appropriately taking French leave, as it were. Overalls acted as an "open sesame"; nobody asked for my credentials, and the informality worked admirably.† At the head of the train was Chapelon "Super-Pacific" No. 231–E45, one of the last of the final ten Paris–Orleans machines built at the Fives/Lille works in 1936–7 (Fig. 2). My good friends Messieurs Leseigneur and Fillon were beside it, having come from Paris on my behalf, as usual, the one to drive and the other to act as courier, so the omens—engine, crew and weather—all being propitious, a pleasant, carefree run to the Gare du Nord was assured.

A few of the principal dimensions of these "Pacifics" (Figs. 3 and 4) are :

Cylinders :	
H.p. (two), outside	16½in × 25½in
L.p. (two), inside	25½in × 25½in
Valve gear : "Lentz" oscillating cam poppet, independent Walschaerts drive.	
Ratio h.p. to l.p.	1/2·32
Receiver volume	10·9 cu. ft
Steam pressure	246 lb
Wheels, diameter :	
Bogie	3ft 2in
Driving	6ft 5in
Trailing	3ft 10in, drivers equalised
Boiler :	
Mean diameter	5ft. 6in
Length between tube plates	19ft 4in
Centre from rail	9ft 4in
Boiler : A.C.F.I. feed-water heater, two Friedman injectors.	
Firebox : Belpaire trapezoidal with Nicholson syphon.	
Firebox :	
Grate area	46·5 sq. ft
Kylchap double blast pipe.	
Heating surface :	
Tubes and flues (inside)	1797 sq. ft
Firebox	164 sq. ft
Syphon	27 sq. ft
Superheater (Schmidt or Houlet)	784 sq. ft
Total	2772 sq. ft
Weight on :	
Bogie	27·5 tons
Drivers	56·25 tons
Trailers	16·4 tons
Total	100·15 tons
Tender	80·0 tons
Coal	9 tons
Water	7700 gallons

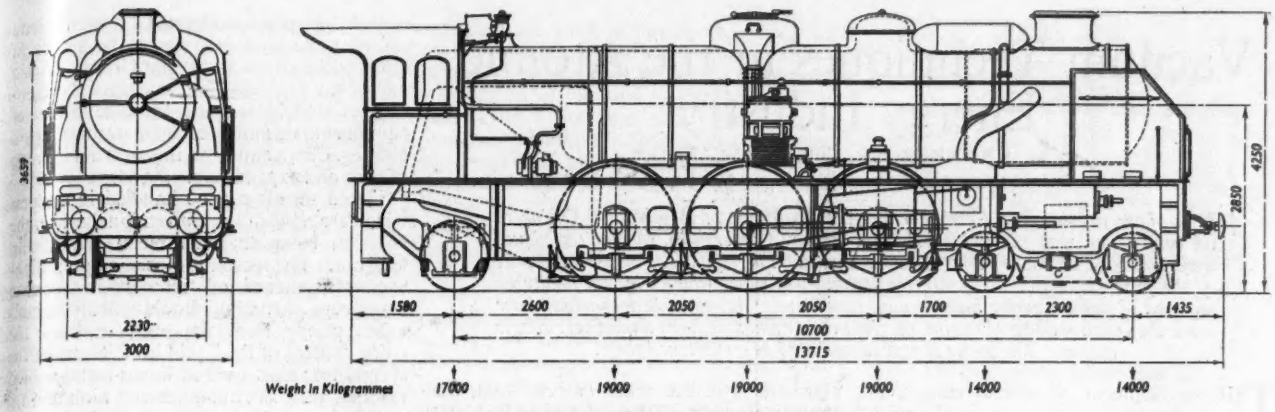
The class was described in greater detail in THE ENGINEER of February 26, 1954.

Train No. 82 got away at 2.48 p.m., 6 min late; this was not the "Golden Arrow," as on previous occasions, but a heavier boat-train, weighing about 550 tons gross, yet despite the moderate adhesion weight, 56·25 tons, there was no trace of a slip—there very seldom is with French locomotives; live steam in all four cylinders, coupled with regulators easily operated and with fine adjustment, account for some of this. With five persons in the cab, room was at a premium and chauffeur Chabe laughingly suggested one of us had better get into the firebox. Mecanicien Budin's duties were easy and not precisely defined, Monsieur Leseigneur being at the regulator. The running speed of this train was much the same as the "Golden Arrow's," but there was a stop *en route* at Boulogne, the load was fairly heavy, and the start had been late, so Chabe would not have much opportunity of relaxing for a while. Looking about the cab, the invariable—and indispensable—Flaman recorder was noticed right in front of Leseigneur, under the window, the best possible position; there was only one water gauge, all that is considered necessary on French engines—and on American—the two provided on British backplates must be custom-bred. I was told the gauge readings were about 2 kg down, but this did not help me much, as all the needles of the triple dial—h.p. and l.p. steam chests, plus boiler—were flickering badly, presumably due to water in the pipes, so only the fireman's steam gauge was truly informative. But there was little need to consult it, as steam was always up near popping-off point, 17 hpz. (×14·2 lb), notwithstanding that the coal was much as usual—logged as "so-so"—somewhat small and dusty, and the engine was steaming perfectly. Of course it was, and would continue doing so! With every steam-raising and disposing feature adequate, passing through ample channels—large grate, syphon, generous heating and superheating surfaces, compound expansion, feed-water heater, and so on—naturally it steamed well, and could do so with inferior coal. "All this and Heaven, too" on a weight of 100 tons! Enthusiasm is excusable when one travels on engines like this; there is still a great deal to be learned from them—and imitated. It is a joy for a lover of locomotives to ride them, and watch them at work.

The long 1 in 120, 7-miles climb up the Caffiers bank was taken at 35–40 m.p.h., rather slower than anticipated, but if I remember rightly, there was a p.w. restriction midway; moreover, the load was considerable, 550 tons, and adhesion, only 56 tons, might have been lost if, following the restriction, the engine had been extended; I did not ask Leseigneur about this, lest he should think me too critical. The summit was passed at 3·11, 7 min late, so another minute had been dropped, for which there must have been some valid reason, as the idea of Leseigneur casually losing time without good cause does not fit in with my quite considerable experience of his driving methods—or of any French driver's methods, for that matter—there is a bonus for time recovery, and it always is recovered if possible.

The next note refers to the firedoor, a feature with me perhaps rather of the order of King Charles's head in the compositions of Mr. Dick, but it is a prominent fitting on the footplate, and merits consideration, being in such constant use—besides, it affects steaming. The French pattern pleases me more than the less practical, primitive doors often seen on British engines. It is in three sections, hinged at the top, opening inwards, balanced by weights serving as handles, and acting as deflectors or baffles at the same time. The sections can be opened in three ways—left and middle, right and middle, or all three together. Next to no physical effort is needed to work them; there is nothing to jam with grit, and if a tube should go when the door is open they close automatically. Nothing could well be better; a simple, efficient device without any superfluous parts. Baffles, often a nuisance, are invariably found on British engines, presumably because the sliding doors make them necessary; provide a better door and they would not be needed. On three occasions, with three different classes of engine, one the last word, I have seen them fall off—they are not fixed, merely resting on projections inside the door—or rather, get knocked off into the firebox, giving the firemen an exasperating, roasting job to get them out. When this proved impossible the fireman had to carry on with the wretched thing in the middle of the fire. Another instance was even worse; the baffle sagged, jamming the door shut, and it had to be opened with a pinch bar, after much trouble, by which time steam had dropped nearly 100 lb—it was an express train, too. When finally the door was forced open, the baffle had dropped so much the fireman could not get fuel to the front of the box, so the baffle had to be smashed off with the coal hammer, and manœuvred out into the cab, where it did its best to set fire to the floor. On Western Region engines the fireman has another unnecessary gadget to cope with, a little hinged flap at the bottom of the door, worked by a chain; I well remember my first acquaintance with this excrescence—the engine was a "King." There was an inspector on the footplate, his presence evidently goading the fireman into such conscientious attention to the thing that he dropped and raised it for every shovelful of coal fired between London and Plymouth, during four and a half hours; literally, every shovelful. He worked like a Trojan—he had to do so in any case, with only a 34 square foot grate and a superficial superheater—pardon, "steam drier"—never letting up from start to finish; firedoor, flap, chain, shovel, flap, door, injector, without respite; one or more was always claiming attention. Not a minute to relax, let alone sit

† But "the best laid schemes of mice and men gang aft agley"—there were repercussions later, on leaving the country at Havre, where it was discovered that my passport was unstamped. Where, when, how and why had I entered France? On explaining, the official looked at me sternly, but with a twinkling eye, saying that never, never again must I behave in such a reprehensible manner. I promised not to, so *that* little scheme won't work any more.



Main dimensions and loading of "Super-Pacific" No. 231E45, S.N.C.F.

down ; watching him, very sympathetic, it so got on my nerves that I offered to manipulate the chain for him, but my well-meant, clumsy efforts were in vain. Never having worked on a chain gang myself, synchronisation was imperfect, his shovel and my chain failing to hit it off except by accident, one generally coming into action before the other was ready. Finally, he thanked me, but suggested that perhaps I had better leave it to him, as he was more used it—undeniably he was. I do not for a moment suppose he would have bothered about the thing if an inspector had not been at his elbow—he was a smart, intelligent fellow. But, alas ! he was intimidated ; not, like Shaw's dustman, Doolittle, by middle-class morality, but by Swindon flap-and-chain immorality reinforced by an inspector. There the thing was, and, under the circumstances, he had to use it ; there it probably still is, and always will be, until the sands of the desert grow cold. Maybe it is one of the imperishable devices that Churchward bequeathed to the locomotive world. Strange that it does not appear to have crossed the Channel—Monsieur Chapelon has not learned the lesson yet. I must impart it to him at the next opportunity—he might be interested.

A query about firedoors. Why are British doors made so small that with a wide firebox it is awkward to get fuel into the back corners, which should never be neglected ? French doors are generous in area and square, giving ample scope for the twist of the shovel, and the flirting of fuel to any point on the grate with precision. Why must the usual kind of British door be oval, and comparatively small ? Is it a law of the Medes and Persians, inasmuch as it always has been so ? Closely related to the firedoor is another footplate feature, the shovel plate ; on British tenders it is generally undersized, the opening into the bunker apt to get jammed by large lumps, especially when the said bunker is full. Sometimes it is set below the level of the firedoor, so the fireman has to shovel uphill, and it is nearly always about 6ft away from the firebox, all these disabilities adding to the labour involved. On a Chapelon "Pacific" it is twice the size, higher than the firedoor, with the front not more than 3ft from it ; further the opening cannot jam with coal—though admittedly I never remember seeing lumps big enough to jam it ! There is no lost motion about the French fireman's stance ; he does not have to do unnecessary work, like his British confrère. These things are by no means trivialities on the footplate ; a little more thought by designers would save the fireman a great deal, and he would have less reason to blaspheme, which he often has a right to do —and does ! If designers would travel on engines more before getting at their drawing boards it would be all to the good ; they would learn useful lessons by crossing the Channel and making a few runs on engines they will find on the other side. With all due respect to the departed, Churchward is no longer with us—Chapelon still is. But to resume the journey to Paris.

Down the south side of the Caffiers ridge the speed held close to the 75 m.p.h. limitation, the two rises between the foot of the descent and Boulogne, both 1 in 120, not being long enough to reduce it substantially. The Boulogne stop was made at 3.24, 42km from Calais in 36 min, a 42 m.p.h. average over a heavy route with restrictions at both ends and in the middle—quite creditable. Restarting at 3.25—they do not linger over station work in France, one notices—we were only 5 min late, 2 min having been picked up from Caffiers. It is easy going from Boulogne right to Amiens, once the Dannes-Camiers bank is surmounted, 5 miles of 1 in 143 ; Abbeville was passed at 4.14, 4 min behind time ; from here there are no gradients worth consideration for many miles, and the speed held steady and high, approaching the limit. The riding, as usual, was perfect—easy, springy, with next to no rolling or nosing, nor irritable reaction to switches and curvature. It was footplate travel at its best, and very enjoyable, this sunny autumn afternoon. The behaviour of the engine was as responsive and harmonious as the atmosphere in the cab, where everybody was friendly and happy, the sharing of English cigarettes resulting in grateful smiles. French tobacco is rather—well, let us say, an acquired taste ; though unlike British, it is worth what you pay for it.

Amiens, where there is a restriction of 45 m.p.h., was passed at 4.38 O.T., 125km in 73 min from Boulogne, a 64 m.p.h. average, the 75 m.p.h. limitation never having been exceeded—regular running, taking into consideration the Dannes-Camiers climb *en route*. Actually, the running speed never exceeded 70 m.p.h. ; had it been allowed to do so we should have got ahead of schedule. French running specialises in steady work under all conditions, not laboured uphill efforts offset by down-gradient dashes, rather indulged in at home. A little beyond Amiens the limitation becomes 81 m.p.h., and at Longueau the 24 miles 1 in 330 pull up, through Ailly-sur-Noye and La Falaise to the Gannes summit, almost uninterrupted, begins ; during this climb the speed never fell below 60. Down the other side, through St. Just and Clermont, it rose somewhat, and Creil was run through at 5.30, 2 min ahead of time—working time must not be bettered by more than 3 min. The 247km from Calais had been covered in 162 min, inclusive of the Boulogne stop, the average working out at 56·7 m.p.h.

Restricted Creil yard passed, the long 1 in 200 Survilliers climb begins, 12 miles through the lovely Forest of Chantilly, and Chabe became busy for the last time. He had been kept well occupied right from Calais, but not to the extent that I had been seriously concerned ; he could smoke an occasional cigarette and was invariably cheerful. Once the summit was reached, everybody in the cab relaxed ; we were on time, and it was all down grade to Paris. The fire was raked and allowed to burn thin, even the pressure to fall, but the speed rose near the 81 m.p.h. permitted. It was a very pleasant finale to a perfect run ; a high-speed flight through Indian summer air, under a full moon shining in a turquoise sky, the twinkling lights of Paris spreading out before us. The weather had been fine throughout, the behaviour and riding of the engine impeccable ; mechanically and socially there had been no flaw. Through St. Denis, with its multiplying tracks, junctions and fly-overs, train No. 82 ran to a stand in the Gare du Nord at 6.10, right on time ; 185km in 202 min, with one stop, an average of 55 m.p.h.

To state unequivocally that the unexpected always happens is a mistake, but in my experience it is close to the truth when one travels on locomotives of the S.N.C.F. ; moreover, the unexpected is apt to be something pleasant, as the following shows. Getting down from the engine, we were greeted by Monsieur Segaud and Monsieur Leroy, in itself an unexpected pleasure ; while chatting on the platform, the group was suddenly invaded by a pretty, vivacious Parisienne, who, greatly to my surprise and temporary embarrassment, embraced and saluted me without restraint, to the delight of everybody, as I was evidently unprepared for this typically Gallic demonstration of goodwill, and apparently unacquainted with the demonstrator. But the embarrassment quickly faded, the action being so spontaneous and human ; this was Madame C——, wife of a chauffeur with whom I had ridden several times during previous visits, and who comes somewhat prominently into one or two past articles. Prevented by duty from coming to Paris in person, he had sent this charming deputy all the way from Creil to welcome me, and request that I would not leave France without visiting them in their "humble home." In essence, *l'entente cordiale* ! Who could fail to be pleased—who could refuse ? But can one imagine such an incident happening at, say, King's Cross or Euston ? No, it could not—on the whole, I am glad it never has—it *would* be embarrassing there ! But this was the Gare du Nord—this was France, where such an uninhibited gesture is quite in place—and "La Maison Blanche" was within easy reach.

(To be continued)

Vacuum Techniques in the Atomic Energy Industry

By H. KRONBERGER, O.B.E., B.Sc., Ph.D.*

No. I

In a paper presented on November 8 at the Institution of Mechanical Engineers (in conjunction with the British Nuclear Energy Conference), vacuum techniques were classified as those used (1) where a vacuum is required as an essential part of the process, and (2) to ensure the tightness of plant which may not finally be required to operate under high-vacuum conditions. Advances in technology have made the construction and testing of plant to vacuum standards a relatively simple matter. The paper is reproduced here in a shortened form.

THE development of atomic energy, in particular the construction of diffusion plants for the separation of the uranium isotopes, has stimulated a rapid development of industrial high-vacuum technology. Before the war the setting up of a large high-vacuum system was a problem approached with great respect and frequently as a last resort, and was considered to require specialised staff, usually physicists, for design and operation. The general use of metal systems had only just become established, and it was not uncommon to see steam and water fittings laboriously adapted to a duty for which they were never intended. The largest diffusion pump commercially available at the end of the war had a bore of 3in. Breakdown of vacuum plant through leaks was a common event; plasticine, waxes and sealing varnishes were generally provided as "operational" materials to deal with these emergencies.

To-day, the design engineer is able to draw on a well-established practice for the design of high-vacuum plant and has at his disposal a wide selection of standard components and instruments. The use of high-vacuum techniques has spread well outside the atomic energy field and has had a marked effect on many industries. Vacuum plant, to-day, is simple and reliable and is usually operated by semi-skilled labour. A number of applications originally developed in the Atomic Energy Authority are now so well established that there is no need to refer to them here; nor is it intended to deal with the rather isolated problems encountered in the construction of the vacuum systems for the large particle accelerators.

Vacuum technology is employed in two distinct fields. The first covers applications in which the vacuum is required as an essential part of the process, as, for instance, in vacuum melting, particle accelerators or in electromagnetic separators. Into the second field fall the applications where vacuum techniques are used to prove and ensure the tightness and often cleanliness of plant, although the plant may not finally be intended to operate under high-vacuum conditions.

Increasing use has been made of vacuum techniques for the second type of application and it is possible that the potential advantages of these techniques are not as widely recognised by industry in general as they deserve.

In the applications discussed in this paper a "vacuum" refers in general to a pressure in the range of 1–10μ (10^{-3}–10^{-2}mm mercury).

Some Applications

The outstanding example of a vacuum system dealing with corrosive gases is the diffusion plant for the separation of uranium 235.[1] It is perhaps not generally appreciated that the U.K.A.E.A.'s diffusion plant at Capenhurst easily forms the largest vacuum system in Western Europe. The length of pipework is of the order of 100 miles, the number of valves of the order of 10,000, and the number of welded and flanged joints of the order of 100,000. With its many thousand stages, each consisting of quite intricate components, such as turbo-compressors, heat exchangers, membrane assemblies, the whole plant forms one continuous vacuum system, so tight that if evacuated and isolated it would take a very large number of years for the pressure to approach that of the atmosphere.

The need for the high degree of tightness lies in the fact that the process gas, uranium hexafluoride, is operated on both below and above atmospheric pressure; air leaking in would not only disturb the separation process, but would also, on account of its moisture content, cause rapid decomposition of the process gas, giving rise to uranyl fluoride dust (which would plug the diffusion membranes and foul the compressors) and to the very corrosive hydrofluoric acid gas. In parts of the plant which operate above atmospheric pressure out-leaking process gas would form a health hazard apart from constituting a serious loss.

When the construction of a diffusion plant was first contemplated the problem of obtaining and maintaining the required degree of tightness was probably considered the most formidable aspect of the project. Estimates were made for the cost of vacuum testing the components, sub-assemblies and the completed plant, based on the testing methods then available; of detecting and locating leaks during operation of the plant, and of the loss of output which would be caused by taking units off line in order to repair the leaks. All these estimates gave very high figures, even when considered against the background of the total capital and operating costs of the proposed plant. It was therefore obvious that particular attention would have to be given to the development of economic vacuum techniques. The problem was attacked essentially on three fronts: establishment of the correct design principles; development of fast-acting vacuum testing and leak-locating equipment, and careful managerial control of inspection and testing procedure.

The results of this concerted attack were most satisfactory. The rejection rate of components on the grounds of leaks fell from the earliest figures of 58 to 10 per cent. The time of vacuum testing of components and sub-assemblies was reduced to one-quarter, or even less in certain instances. Finally, under operation the diffusion plant maintained a standard of tightness higher than was thought possible.

The possibility of using molten metals, particularly those of the alkali group, as nuclear reactor coolants was recognised quite early. As a consequence, considerable development of liquid-metal technology took place. The Dounreay fast reactor project and certain feasibility studies on a sodium-cooled, graphite-moderated reactor have caused quite large test rigs to be set up in laboratories of the Industrial Group. Again one of the problems was to ensure the tightness of quite large and intricate pieces of equipment, this time at temperatures up to 600 deg. Cent., and to do this with a minimum of time and expenditure.

Liquid metals can be handled in systems which are tight in the conventional sense, the criterion being that the metal should not leak out. The reason for insisting on a high-vacuum standard of tightness for certain equipment handling liquid alkali metals arises chiefly from the need to keep the oxide content of the liquid low. Some of the special materials used in liquid-metal-cooled reactors such as zirconium and niobium are attacked by quite small concentrations of sodium oxide. It is, in general, necessary to keep the oxide concentration in such a reactor between 10 parts and 20 parts per 1,000,000 (in certain instances even lower). Methods had to be developed for achieving these limits on quite large quantities of sodium and also to monitor continuously the oxide concentration of such a system to an accuracy of a few parts per 1,000,000.

Obviously the equipment in which this development work was done had to be very tight, and so had the apparatus in which the attack of various concentrations of oxides on special reactor materials were studied. The vacuum techniques which were available in the Industrial Group laboratories were well suited for this work, although the high temperature involved added new problems.

Water at high temperature, particularly in the presence of radiation, is a very corrosive fluid. In the development work on various forms of high-pressure water reactors emphasis has therefore been laid on studies of the corrosion problems. This work is carried out in autoclaves and circulating loops, some introduced into experimental reactors to assess radiation effects. Corrosion is dependent on the concentration of dissolved gases such as hydrogen and oxygen, and the very sensitive tests require that the gas content be known and the gas evolution measured and controlled. Furthermore, it is usually essential in such investigations that there should be no loss of water from the system.

To meet the stringent specifications all equipment was designed for a high-vacuum standard. An example is a plant in which the corrosion of fuel cans is studied at temperatures up to 350 deg. Cent. (662 deg. Fah.) at a pressure of 2500 lb per square inch and at heat fluxes of 3 to 6×10^5 B.Th.U. per square foot hour. The plant embodies extensive facilities for water treatment, water and gas analysis and is thus fairly complex, yet the leak rate of the whole system on evacuation after temperature cycling is as low as 10μ per hour. In the high-temperature sections fully trapped solid nickel rings are used as gasket material. To ensure reliable and reproducible assembly of the flanged joints the specially finished bolts are tightened up until they reach a predetermined extension.

A heat exchanger element for the Calder reactors[2] consists of a tube of 1½in to 2in outer diameter, up to 300ft long; each of the four heat exchangers is made up of 1000 of these elements. It is essential that the risk of water leaking into the carbon dioxide circuit, that is, into the reactor, should be reduced to a minimum. The permissible leak rate of the complete exchanger was set at 2½ lb of water per hour, which could be continuously removed by a drying plant. For

* United Kingdom Atomic Energy Authority, Industrial Group Headquarters, Risley.

[1] Jay, K. E. B., *Britain's Atomic Factories*, page 43 (H.M.S.O.).

[2] *Journal Brit. Nucl. Energy Conf.*, 1957, Vol. 2, page 176.

a structure of this size this represented a very high standard of tightness. Expressed as a vacuum leak, that is, from atmosphere to vacuum, the specification for tightness appeared even more stringent, since the mass of air entering from atmosphere through a leak of a given dimension would, in general, be very much smaller than that of water, on account of the lower kinematic viscosity (η/ρ) of air and the smaller pressure difference. The exact correlation depends on the type of leak and the flow mechanism inside the leak, but it was estimated that, allowing for the worst conditions, the maximum permissible leak rate as measured by a vacuum test would have to be as low as 2 clusecs.[3] The problem was to detect such a leak which might occur at the far end of a tube of 1½in outer diameter, 300ft long, bearing in mind that the inside of the tubes was likely to be quite "dirty" by vacuum standards, and might on degassing yield as much as 20 cubic centimetres of oily water as trap residue.

Fortunately the charcoal-Pirani technique, using hydrogen as probe gas had by that time been firmly established in the laboratories, and tests showed that a 2-clusec leak could easily and quickly be detected on a heat exchanger element under the worst conditions. A test rig was set up at the maker's works. The elements were evacuated by a "roughing" pump to about 30μ pressure, then the main pump unit was brought into line and the system stabilised. For calibration hydrogen was supplied to the standard 2-clusec leak and the response of the Pirani gauge noted. The standard leak was then isolated and the heat exchanger element under test was enveloped in a balloon fabric[4] bag which was filled with hydrogen. The response under these conditions was then compared with that obtained for the 2-clusec standard leak. On the average twelve elements were tested in a day.

This example forms a typical illustration of the application of vacuum techniques in instances where the object is to prove the tightness of a system rather than to obtain a vacuum under operating conditions. With the method described it is not required to have the test object "clean," that is, free of volatile impurities, although for very dirty components it is necessary to interpose liquid nitrogen or solid carbon dioxide traps to prevent contamination of the pump oil by water and other volatile impurities.

Design

Vacuum tightness starts at the drawing board. The success and economic operation of vacuum plant and vacuum testing methods depends more on good design than on the extreme performance of the pumping and measuring equipment which is available commercially nowadays.

Although the principles of design of vacuum plant have been described in a number of publications, it may be useful to record some considerations which have been found particularly important in the various applications mentioned above. Materials of construction are essentially determined by the operating conditions of the plant (temperature, corrosion resistance, pressure). Plant should be constructed, whenever possible, from rolled plate or forgings. In the author's experience, castings have never been satisfactory as vacuum envelopes, whether centrifugally cast, metal sprayed or plated in an attempt to eliminate porosities. Under certain conditions castings are acceptable *inside* vacuum systems. If organic materials are used, attention must be paid to their vapour pressure. Certain rubbers contain large amounts of volatile impurities which must be removed by degassing before use. Plastics are finding increasing use in vacuum technology. Outstanding examples are fluorinated polymers, such as polytetrafluor-ethylene, which were originally produced in large quantity as UF_6-resistant materials for the British and American diffusion plant projects, but which have found widespread use in many branches of engineering.

Most materials hold gases and vapours in solution or in adsorbed layers. In plants where a high degree of vacuum is required, or in static (permanently sealed) systems, degassing at elevated temperature is required; this procedure must be allowed for in the design. Glass, incidentally, can hold large quantities of water on the surface and in solution, but recent information has indicated that the equilibrium vapour pressure is quite high, 10mm at 500 deg. Cent. (932 deg. Fah.), so that prolonged heating of glass in dry air should be adequate to remove most of the moisture.

Whenever possible, connections should be made by welded joints rather than flanges. Argon arc techniques have contributed considerably to the reliability of welded vacuum joints, and are almost exclusively used by the U.K.A.E.A. for welding vacuum equipment. Full penetration should be aimed at; trapped volumes cf gas and crevices in which contaminants can collect must be avoided. The use of "Tee" backing strip is not recommended, since it gives rise to trapped volumes (Fig. 1).

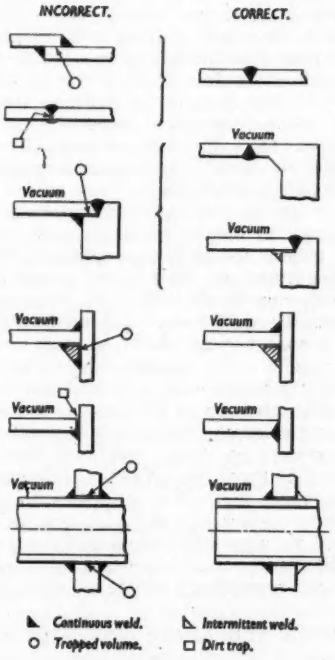


Fig. 1—Welding of vacuum equipment: examples of good and bad practice

For flanged joints fully trapped rubber rings of square or round cross-section are used. The flanges must be designed so that there is metal-to-metal register when fully tightened; this ensures dimensional accuracy and a predetermined compression of the rubber. Recommendations for the optimum compression of various sections of rubber are now supplied by the makers.

An improved design of coupling is shown in Fig. 2. The two flanges forming the joint are identical. They are brazed to the pipe in a jig by induction heating. Once the correct setting of the induction furnace has been determined, reliable and reproducible brazing is carried out in less than one minute. It is almost impossible to make a joint unless the pipe is correctly aligned and of the right length. The joint is tightened until there is contact between the flanges; this ensures that the rubber is under a predetermined compression. The improvement in quality of assembly, as expressed by the reduction of vacuum testing time and by the reliability in service, fully justified the introduction of this design.

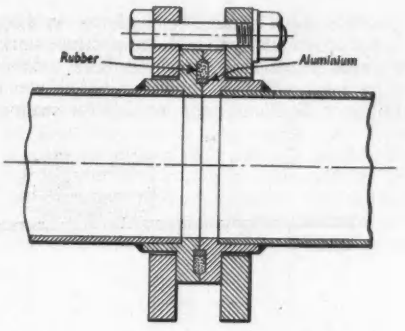


Fig. 2—Improved vacuum coupling

For plant of large volume, consisting of many units or components, the double O-ring joint deserves particular attention. Before assembly into a plant each unit will have been tested separately so that after assembly it should only be necessary to test the joints by which the component has been connected to the plant. This can be done quickly, without evacuating a large plant volume, by providing two concentric sealing rings (usually O-rings) in the flange (Fig. 3). A drilling in the flange connects with the space between the two rings. By a suitable pipe connection this "interspace" between the O-rings can be evacuated. The joint is vacuum tested, with the plant at atmospheric pressure, by merely evacuating the small volume formed by the interspace and determining its pressure rise on isolation. The saving in time, as compared to having to evacuate the whole plant for testing, is considerable. The interspace design has the added advantage that it is possible when the plant is in operation to introduce a tracer gas into the interspace of a suspect joint; this tracer can then be detected inside the plant, if the joint leaks.

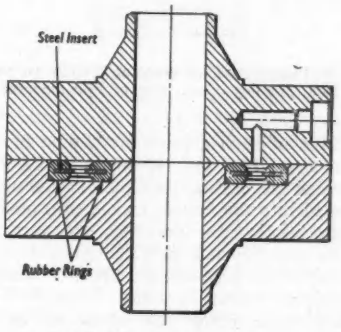


Fig. 3—Flange with "interspace" joint

For ease of assembly the double O-ring can be manufactured as a single moulding, the cross-section of the ring being in the form of a dumb-bell.

The remark made earlier that whenever

[3] One clusec is a leakage rate which causes a pressure rise of 1/100,000mm mercury per second when leaking into a volume of 1 litre.

[4] Balloon fabric is sufficiently conducting to prevent static electricity build-up which might ignite the hydrogen.

possible joints should be made by welding, applies particularly to high-temperature work. Flanged joints have, however, been successfully used. Fig. 4 shows a design which utilises a hexagonal copper ring for sealing.

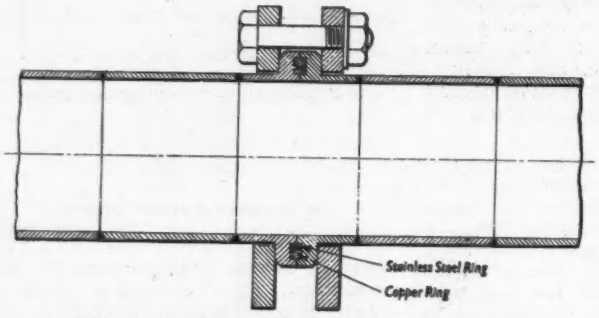


Fig. 4—Flange joint with copper gasket for liquid sodium

With careful design joints of this type remain vacuum tight up to 200 deg. Cent. (392 deg. Fah.) even after extensive temperature cycling. For higher temperatures a trapped joint similar in principle to that shown in Fig. 5 is used.

For the application as described earlier, a flanged joint to operate at 2500 lb per square inch pressure and 350 deg. Cent. (662 deg. Fah.) was developed. Fig. 5 shows an

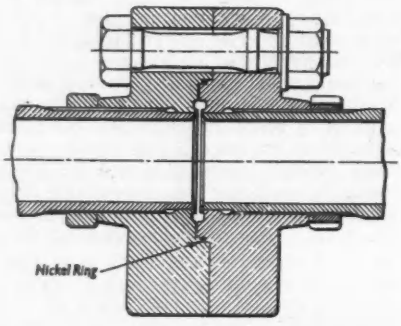


Fig. 5—Flange joint for water at 2500 lb per square inch, 350 deg. Cent., pipe of 2½in diameter

example of such a joint for a pipe of 2½in diameter. The seal is made by a fully annealed nickel ring, ⅛in square. The pipe is screwed into the flange, locked into position by the backing nut, and then expanded into the flange. A seal weld is then made between the end of the pipe and the lip of the flange ; the screw thread is thus " outside " the system. The flanges are made of 18/13/1 stainless steel, the bolts of FVS stainless steel with a thermal coefficient of expansion close to that of the flanges. In order to obtain reproducible vacuum-tight and pressure-tight joints at all temperatures, without overstressing the bolts, it was considered necessary to control the tension of the bolts when making the joint. This was done by tightening each bolt to a predetermined extension ; the ends of the bolts were specially finished so that the extension could be measured by means of a micrometer.

For very low temperatures, for example, liquid nitrogen −190 deg. Cent. (−310 deg. Fah.), rubber cannot be used for sealing flanged joints as it contracts and becomes very hard and brittle on cooling. Indium, however, stays soft at these temperatures. Satisfactory flanged joints have been made for low-temperature work by using fully trapped indium metal O-rings.

Many designs of vacuum valves for general use have been described in the literature or are now commercially available and need not be discussed in detail in this paper. The valve spindle can be sealed by a packed gland (" Teflon " rings form an excellent packing material), by O-rings, diaphragms or bellows. The choice depends on the operating conditions ; for most applications in the atomic energy projects various forms of bellows seals have been used. In the earlier days the bellows were considered the weakest and least reliable component of vacuum plant and a careful metallurgical study was made of failures and conditions leading to failure, particularly in the presence of fluids which could give rise to stress corrosion. The annealing of formed bellows had to be carefully specified to ensure removal of stress concentrations in the convolutions. The technique of soft-soldering bellows into end fittings was particularly critical. The slightest trace of acid fluxes remaining even after careful washing caused failure in brass bellows after a few weeks. Acid fluxes were, therefore, excluded from any shop in which bellows were assembled. It is well known that valve design has to ensure that the safe travel of a bellows is not exceeded ; less frequently recognised is perhaps the fact that incipient cracks can be introduced into bellows by the almost irresistible temptation to squeeze up a bellows once it gets into one's hands ! In certain cases failures of bellows have been traced to vibrations which have excited resonant frequencies in the bellows.

For high-temperature applications stainless steel bellows have been extensively used, in particular the kind which consists of a stack of thin " washers " joined by circumferential welds to form a bellows.

For use in high-pressure work it was necessary to employ packed glands rather than bellows for sealing the spindle. Where the high pressure, 2500 lb per square inch, was also associated with high temperature, 350 deg. Cent. (662 deg. Fah.), neither Teflon nor rubber O-rings could be used to seal the spindle. The problem was solved by sealing the spindle with ordinary steam packing, but introducing a second seat, back-seat, against which the valve plug seated when fully open. The steam packing is therefore exposed to the working fluid only during the short time the valve is operated. The working surfaces of the plug are stellite-coated, the seats are stainless steel. A typical leakage figure across the seat, at temperature, and after temperature cycling is 1 clusec.

Vacuum Testing and Leak Detection

In the earliest days of the project, vacuum testing and the location of leaks was a tedious operation, depending a good deal on the skill and judgment of the operator. When the construction of the first diffusion plant was imminent, the establishment of quick and positive leak location techniques became an economic necessity.

Some typical methods are listed below. The suitability of the different techniques often depends on the nature of the components or plant under test ; the sensitivity may also vary with circumstances. The charcoal Pirani technique was developed fairly early and proved simple, quick and sufficiently sensitive for most purposes ; the equipment required was cheap. It therefore became the standard method and work on most other techniques was discontinued.

Leaks into vacuum systems are usually expressed as litre-micron per second (" lusec "). A practical unit is the " clusec " ($=10^{-3}$ lusec), which is the leak which causes a pressure rise of 10^{-3} micron per second in a volume of 1 litre.

Isolation Pressure Rise Method.—This is the most direct method, but the slowest. The component is evacuated, and the pressure rise is determined after isolation from the pumps. Before this test can be applied the system must be outgassed for considerable time (often many hours) until evolution of air and other gases from inside the system has dropped and the background is sufficiently low. " Traps " cooled with liquid nitrogen are used to reduce the amount of condensible gases. The progress of the cleaning-up or outgassing process is judged by comparing the rates of pressure rise with and without the cold traps in the circuit. If the pressure rise, even after prolonged outgassing, is higher than tolerable, a leak is assumed to be present. The leak can then be located by surrounding the suspected part with hydrogen and noting the pressure rise. Since hydrogen diffuses through the leak faster than air and since certain pressure gauges are more sensitive to hydrogen than to air, an increased rate of rise of pressure indicates that the leak is in the region which is probed with hydrogen. The method is obviously slow, the only advantage that can be claimed is that if the isolation pressure rise is satisfactory the component is not only proved tight, but also reasonably free of volatile impurities.

Mass Spectrometer Method.—Obviously, if the probe gas can be distinguished from the general background of gases in the system under test, it is not necessary to wait until the system has been degassed. A number of " simple " mass spectrometers have been designed specially for the purpose. Some display the spectrum of gases on a cathode-ray screen ; if the probe gas is brought near the leak, the appropriate mass peak can be seen to grow on the screen. Others are tuned to a particular probe gas (usually helium) and the strength of the signal is indicated on a meter or is made to give an audible signal. These instruments can be made very sensitive, particularly when used with helium as a probe gas. In small volume components (of the order of litres) leaks of the order of 1/1000 clusec or less can be detected.

Unfortunately, even simple mass spectrometers are expensive and require highly skilled servicing ; moreover, the most suitable probe gas, helium, is too expensive to be used for general vacuum testing of large-scale equipment. In the work of the U.K.A.E.A.'s Industrial Group, mass spectrometers are therefore only used for leak detection in special instances.

Differential Pirani Gauge Method.—This is one of a number of methods in which the pressure-indicating gauge is made to discriminate between the probe gas and the other gases present. Two Pirani gauges are used in a differential circuit, one connected directly into the system, the other with a chemical absorbent interposed between gauge and vacuum system. In one version calcium hydroxide is used as the absorber and carbon dioxide as the probe gas.[5] The differential signal from the pair of gauges is therefore essentially due to carbon dioxide. Under laboratory conditions this method has been found very satisfactory, particularly if the gauges are used between two diffusion pumps, in which case pressure fluctuations are greatly reduced. In a number of plant applications,

[5] Bleaney and Lock, *Brit. Journal Appl. Physics*, 1951, Vol. 2, page 227.

however, the absorption of impurities on the calcium hydroxide caused trouble and required frequent renewal of the absorber. The minimum detectable leak, in small volumes, is of the order of 1 clusec.

Hydrogen Palladium Gauge.—The pressure-indicating instrument (a Pirani gauge or preferably an ionisation gauge) can be separated from the vacuum system by a barrier of palladium which, when hot, is permeable to hydrogen only. The instrument therefore indicates hydrogen which may be present as a background gas or as the probe gas entering through a leak. The basic principle is slightly complicated by the fact that residual oxygen and hydrogen react on the hot palladium surface. However, by comparing the response from a standard leak with that from the component under test, the leak rate can be assessed. Fairly high sensitivity can be achieved (1/100 or 10^{-2} clusec in a litre volume). Again, as with the method described under "Differential Pirani Gauge Method," care has to be taken that the instrument is not poisoned by impurities. The permeability of palladium is adversely affected by impurities and for this reason the method was not extensively used in plant work.

Charcoal-Pirani Method.—Charcoal at low temperature absorbs hydrogen less readily than it absorbs any other gas (with the exception of helium). Hence, a charcoal trap, cooled with liquid nitrogen or solid carbon dioxide, placed between a Pirani gauge and the vacuum system under test will ensure that the gauge preferentially responds to hydrogen. This device has been found so reliable and simple that it has been introduced into most vacuum testing installations of the Industrial Group of the U.K.A.E.A.[6]

In general the smallest detectable leak is between 10^{-4} and 10^{-3} litre-micron per second (1/100 to 1/10 clusec).

Calibrated Standard Leak.—Most leak testing methods are not absolute, but require a calibrated leak for comparison to make them quantitative. Surprising as it may seem, the manufacture of stable leaks of a given size proved quite difficult. The most commonly employed leak, a capillary tube flattened by rolling, is particularly unstable and not easy to set. The development of the powder leak (British Patent No. 744,066) solved the problem and was in no small measure responsible for the successful operation of the charcoal-Pirani method. Specially treated aluminium powder is packed between sintered metal discs and compressed by means of a bolt. The value of the leak is determined by the quantity and grade of the powder and the amount of compression. The leak can easily be manufactured to a predetermined given value and remains stable for many months.

Organisation and Management

The success of large-scale application of vacuum techniques in industry depends as much on good management as on the excellence of the equipment used. In fact, for a project of the size of the diffusion plant the problems are those of organisation rather than of technical application, once the fairly simple design principles have been introduced, and reliable testing methods developed. Even in the laboratory a central organisation for vacuum testing and degassing of equipment was found necessary at an early date; this was placed under a senior engineer directly responsible to the Engineering Research Manager and operated on the same general lines as a factory inspection department.

Every component manufactured in the laboratory or purchased was first subjected to an acceptance vacuum test. The component would usually be tested again as part of successive sub-assemblies of increasing complexity. Finally, when the sub-assemblies were built into a "rig," this was tested as a whole. Each test was accompanied by a certificate and whenever a rig was modified or a certified joint broken into, a fresh certificate was issued before the rig was handed over to the operating team. It must be appreciated that many of the apparatuses and rigs used in the laboratory are of quite substantial size; an experimental arrangement may involve over fifty valves and many hundreds of joints, yet rarely requires, at present, more than two days' final vacuum testing.

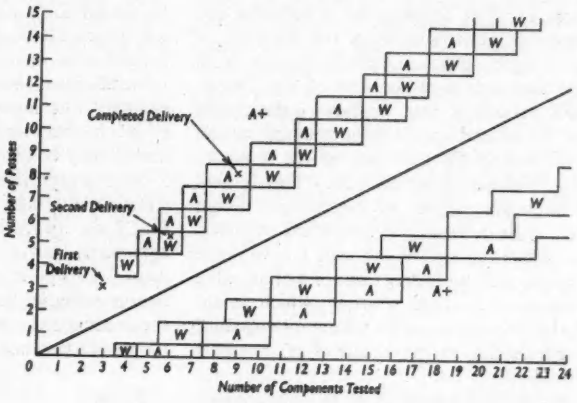
This system which was evolved in the laboratories was adopted with very few modifications for the Capenhurst diffusion plant, and although experience since has found several ways in which some of the tests can be avoided, and the administration has become to some extent decentralised, the methods and organisation have stood the test of time. The factory vacuum organisation at present consists of sections for (1) acceptance testing of new components (valves, vessels, &c.) delivered from outside contractors; (2) acceptance testing of pipework erected by the construction teams or by contract labour; (3) testing and degassing of components and assemblies in workshops; (4) testing and degassing of portions of plant on first commissioning or on re-commissioning after being broken into for maintenance; (5) maintaining and testing of vacuum pump equipment. All sections, except (4) are responsible to the Works Engineer through his appropriate deputies; sections (4) are responsible to the Works Manager through operating Shop Managers.

At present the great majority of components supplied to the factory and to the laboratories are vacuum tested at the manufacturers to a U.K.A.E.A. Standard Specification. Failures on arrival are now rare and seldom exceed 1–2 per cent.

Ordinary statistical quality control methods for acceptance inspection of the "go—no go" kind depend on the assumption that failure rates will usually be less than 10 per cent. They are based on Poisson's distribution for the frequency of occurrence of rare events, and are well described in British Standard 1313 (1947).

With early supplies of experimental components for the laboratories, vacuum test failure rates were usually above 20 per cent and often above 50 per cent. Failures were therefore not "rare" events. Also, there was no convenient lot size for sampling; all items were tested. Deliveries came at approximately weekly intervals in small lots, from two or three items, to a few dozen. Fundamentally, however, the statistical problem was the familiar one of classical inspection: of distinguishing real variations in rejection rate (improvements or deterioration) from variations that could be due to chance. Once variations were proved significant and not due to chance, the causes of improvement or deterioration could be traced.

The method adopted used charts based on the binomial distribution (Fig. 6). These were not strictly control charts since no plot of successive results was marked on them. Each chart showed the limits of variation due to chance that could be expected in the number of "passes" found in any random sample of given size. It was assumed that the samples were drawn from a hypothetical large population containing the number of passes stated in the chart, 50 per cent with the chart shown in Fig. 6. Separate charts were prepared for other pass rates, for example, 60, 75 and 90 per cent. Sets of charts were issued to foremen of the various test sections.



W—Warning limit probability between 10 per cent and 2·5 per cent.
A—Action limit probability between 2·5 per cent and 0·5 per cent.
A+—Action limit probability less than 0·5 per cent.

Fig. 6—Vacuum test control chart for 50 per cent pass rate

The charts were then used in the following way:

(1) For each component and source of supply a running record of test results in terms of "passes" and "failures" was maintained.

(2) From this record, at suitable intervals, for example, weekly, a "previous per cent pass rate" based on the last seventy-five to 100 items delivered was calculated for each component and source of supply. This rate was rounded to the nearest value for which there was a chart.

(3) As deliveries arrived and were tested, the appropriate chart for the previous pass rate of the items concerned was consulted and the actual number of passes in a particular delivery (vertical ordinate) compared with the limits of expectancy shown against the particular total number of items in the delivery (horizontal ordinate).

The following type of action was then taken:

(1) If the actual number of passes fell between the limits, none.

(2) If it fell outside the outer "action" limits, this was taken as proof that delivery was in some way really better or worse than its predecessors. Manufacturers were informed and the delivery closely examined for the cause.

(3) If outside an inner "warning" limit but inside the corresponding "action" limit, this was taken as a strong indication (but not proof) of a change, and further indications of a change were sought. One way of seeking this, for example, was to pool the results of several small successive deliveries and consult the chart again, treating the whole as one larger delivery.

(*To be continued*)

[6] Kent, T. B., *Journ. Sci. Instrum.*, 1955, Vol. 32, page 132.

LETTERS AND LITERATURE

Letters to the Editor

We do not hold ourselves responsible for the opinions of our correspondents.)

THEORY OF SHAFT WHIRLING

SIR,—Dr. Downham's articles on the theory of shaft whirling are a valuable and interesting contribution to the solution of this complex problem. Probably the most important aspect of the first of Dr. Downham's articles is that he shows quite clearly how the critical speed of the rotating system is affected by the elasticity of the structure carrying the rotating element. This is now an important aspect of mechanical design in many fields besides aeronautical engineering. Since the end of the war, I have come across several interesting examples of machine vibration and shaft whirling which could only be fully explained by taking into account the effects due to the elasticity of the shaft mounting.

Two distinct examples of this phenomena occur in vertical-spindle bore-hole pumping plant. Such installations normally consist of a centrifugal pump at the bottom of the bore-hole and a vertical-spindle electric motor at the top. The motor itself is mounted on a fabricated steel stool which is necessarily asymmetrical. Measurements show that the vibrations of the complete motor, in the horizontal plane, are elliptical. The direction of the major axis of the ellipse depends on the speed of the motor exactly as shown in Dr. Downham's Fig. 8. Unfortunately, Dr. Downham's analysis cannot be applied directly to this problem as it is necessary to take into account the inertia of the motor stator as well as the elasticity of the stool on which it is mounted.

There may be some 200ft or 400ft of shafting between the pump and the motor. This shafting is supported in bearings inside the rising main at intervals of 8ft to 10ft. The bearings are carried in special supports at the joints between the sections of the rising main pipes. Such a system as this obviously has many natural modes of vibration, but when it is possible to observe the vibrations, it is usually found that the system vibrates with a frequency which is about 40 per cent of the rotational frequency. The number of nodes and the distance between them is such that the calculated value of the corresponding critical speed is in reasonable agreement with the observed frequency of vibration provided that due allowance is made for the elasticity and inertia of the rising main as well as for the elasticity and inertia of the shaft itself. It is important to note that these phenomena have been observed in plant running at comparatively low speeds such as 1000 or 1500 r.p.m., so that it must not be assumed that if the running speed of a particular installation is low then the elasticity of the shaft mounting can be ignored in critical speed calculations.

Dr. Downham, in common with Captain Morris, is very critical of the theoretical approach to this problem as developed by Dunkerley and Chree. Dr. Downham is naturally quite correct in his criticisms of the methods due to Dunkerley and Chree. Nevertheless, I think it would be a great pity if the method were omitted from our text-books and lecture courses as a result of these criticisms. The great merit of the method is that mathematically it is very simple and can be taught to students who have not studied the theory of forced oscillations. Also, and I think this is most important, it is easily relearnt when necessary by the practising engineer who has not made a detailed study of mechanical vibrations and whose mathematics may be rather rusty.

Several experimental investigations of shaft whirling have been made in the past, but none that I am aware of have shown such good agreement between calculation and measurement. This good agreement is of great practical importance because it shows clearly that if critical speeds are carefully calculated then the results can be used with confidence.

W. G. CRAWFORD

Alloa,
November 8, 1957.

THE MOTOR SHOW

SIR,—As public relations consultants for Isetta of Great Britain, Ltd., we feel we ought to draw your attention to a misleading statement in an article published in your November 1 issue. You say: "The German B.M.W. 'Isetta' to be made under licence in this country by Isetta of Great Britain, Ltd. . . ." In fact, more than 2200 of the Isetta "300" models have so far been assembled at the company's Brighton works. The works commenced production in May of this year. Ninety-one British firms supply material which represents 64 per cent of the ex-works selling price of the vehicle. The remainder of the parts are at present being imported from Western Germany. The first production model of the new Isetta "600" will come from the works in May of next year.

ERIC GOULD,
Press and Public Relations, Ltd.

Berners Street, London, W.1,
November 11, 1957.

TECHNOLOGY AND WISDOM

SIR,—How I hated Latin! And how I begrudged a Christmas holidays spent in swotting for "Littlego" when it might have been spent beagling! But looking back I am in no doubt that the university authorities were right. That painful study has saved me thousands of hours of unproductive toil and I dare say has helped create some tens of millions of pounds' worth of wealth. Loose speech leads to loose thinking: sloppy writing to confusion. Cleverness seldom achieves without a clear head. The worst fault of the ordinary red-brick institution is that it does not insist on clarity of expression (Floreat the exceptions).

The successful technologist is always a clear thinker (how easily one can understand a real master!); the mediocre (and the wicked) are usually that way, not from stupidity or lack of opportunity, but because they flounder in a viscous slough of muddle which blinds them and frustrates their struggles.

It is common to confuse "teaching" with training (or practice) so syllabi bulge with complication. Teaching should be simple, to the point and of the essence with every distraction firmly kept away. Training gives facility in the use of what has been taught; the complications and distractions of practical life may need to be introduced step by step if the weaker pupil is not to lose heart. Schools and universities should teach—apprenticeships and life should train.

Wisdom comes later to most clear thinkers and rarely to the muddle-headed. Latin will help. Greek, I suspect, is a distraction.

JOHN R. D. WALKER

Barley,
Near Rugby,
November 5, 1957.

Book Reviews

Proceedings of the Fourth International Conference on Soil Mechanics and Foundation Engineering. Vols. I and II. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price £17 10s.

THE papers, 179 in number, presented to the fourth International Conference on Soil Mechanics, held in London during August, 1957, are published in these two volumes, together with the General Reports in each of the six divisions into which the contributions have been classified. A third volume is to be published as soon as possible, and this will be included in the price of the *Proceedings*: it will contain a record of all the discussions of the papers, the opening address by Professor Karl Terzaghi and the decisions made during the conference by the executive committee. The printing and format of the volumes are excellent and the editorial work has been carried out with scrupulous care. A general idea of the scope of the conference can be gained from the headings of the divisions, the numbers of papers in which are given: Soils Properties and their Measurement (forty-six), Technique of Field Measurement and Sampling (nine), Foundations of Structures (sixty-one), Roads, Runways and Rail Tracks (twenty), Earth Pressure on Structures and Tunnels (thirteen), Earth Dams, Slopes and Open Excavations (thirty).

In the first division several contributions deal with regional studies and among these may be mentioned papers by Meigh and Early on the Chalk, Skempton and Henkel on the London Clay, and Mohan on the Indian "black cotton" clays. Eden and Crawford describe the clays of the St. Lawrence Valley, showing that many similarities exist with the "quick" clays in Scandinavia. Loess soils in Israel and Argentina are described by Kassiff and by Bolognesi and Moretto. Another group of papers in this division shows that the importance of pore pressures in problems concerning the shear strength of soils is now very widely acknowledged, but there is still need for research on the influence of the intermediate principal stress on the failure condition. Kirkpatrick, for example, finds little difference between the angle of internal friction in sand as tested in tension and compression, whilst Peltier reports appreciable differences.

In the second division interest lies chiefly

in the *in situ* penetration tests. There are obviously too many types of these useful but empirical tests, and some degree of international standardisation is urgently required. The paper by Schultze and Knausenberger should be valuable in this connection. The importance of sampling methods is emphasised, with quantitative data by Serota and Jennings, whilst a reference to the very promising gamma ray method of measuring density *in situ* is made in a paper contributed by four Russian engineers.

On the subject of foundations, field experience concerning the failure of an oil tank is given by Bjerrum and Overland, the distribution of pressure under a raft by l'Herminier, and Kerisel has observed the distribution of load around a deep pier. Useful data on allowable settlements are contributed by Polshin and Tokao, who also give comparisons between calculated and observed settlements ; as does Egorov for seven large buildings in Moscow and Simons for two structures in Norway. Valuable tools in the estimation of settlements are the stress distribution tables by Osterberg and the three-dimensional consolidation solutions by Gibson and McNamee. Field evidence on the overturning of foundations is contained in papers by Lazard and Roscoe, whilst interesting practical foundation problems relating to high buildings are discussed by Williams, for London, and de Mello for Sao Paulo.

An increasingly important factor in modern soil mechanics is the collection and correlation of available field evidence on particular subjects, and Tomlinson's paper on the side friction on piles in clays is a good example of the practical value of such work. Other contributions on piled foundations include an interesting series on the buckling of piles in soft clay and a description of the vibratory method of pile-driving. In the realm of airfields and roads useful data on pore pressures under grass and concrete pavements are given by Black and Croney, and on plate tests by McLeod and Moraldi. Lambe presents a summary of recent work on soil stabilisation, and several authors discuss compaction and pavement design. Valuable field observations are reported by DiBiagio and Bjerrum on a strutted excavation, by Lane and by Ward and Chaplin on tunnels, and by Tschebotarioff on sheet-pile walls. In this division, dealing with earth pressure, the General Report by Kerisel is notable as giving an excellent summary of the advances made during the four years since the previous conference in Zurich.

The sixth division, concerned with earth dams and slopes, includes two case records of long-term failures in London Clay analysed by Henkel, and a survey of natural slopes in this clay by Skempton and DeLory. Other landslides are described by Hurtubise and Meyerhof, by Peynircioglu and by Vargas and Pichler. Pore pressure observations in earth dams are recorded by Bernell and Nilsson, Bishop, Finzi, Nonveiller and by Schiltknecht and Bickel. All these papers show that a great deal of attention is now being paid to field observation and, indeed, the *Proceedings* as a whole contain a wealth of data indispensable to both practising and research engineers.

Project Engineering of Process Plants. By HOWARD F. RASE and M. H. BARROW. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 114s.

THE authors, in a single book, have endeavoured to record information and techniques covering, in general, the whole field of chemical plant design, procurement and erection, over which the project engineer exercises control. They have recognised that the project engineer, by his experience and training, must have sufficient knowledge to co-ordinate the activities of all the technical specialists and non-technical staff employed on the design and erection of a process plant. In categorising the manifold responsibilities and procedures which have to be considered by the project engineer, the book provides a considerable amount of information, much of which will be superficial to people active in this work. A wealth of references, bibliographies and reviews, mainly from American sources, are included, however, from which detailed information would be available.

The book has been written not only for the project engineer and those designing process equipment, but also as a text for chemical engineering plant design courses. The information which is given on business, legal and office procedures and on various kinds of contracts, will be of value to chemical engineering students by augmenting their specialised technical studies. A large section of the book is devoted to engineering design and equipment selection but adds little to the knowledge gained, in this country, by engineers through their technological courses and normal development in their profession. The use of models as a new technique in design drafting and construction and as a powerful aid to the project engineer, is a subject of increasing importance. They have been used, in the United States, by many companies specialising in process plant design and construction and substantial economies have resulted. A reference, by the authors, to the use of models could with advantage have been included in this book.

Applied Mechanics. By R. C. STEPHENS, M.Sc., and J. J. WARD. Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 12s. 6d.

THE declared object of this book is to prepare students for examinations in applied mechanics for the Ordinary Certificate in Mechanical Engineering. It treats basic principles concisely and adequately and it contains a large number of appropriate examples (with answers) to be worked out by the reader. This feature alone would make the book admirably suited to its purpose and it can be confidently recommended to anyone who would ground himself thoroughly in the elements of the subject. The book is not a textbook in the ordinary sense, but as a summary of textbook material or as an adjunct to a course of lessons it is excellent.

Books Received

Civil Engineering. By K. L. Nash. Robert Hale, Ltd., 63, Old Brompton Road, London, S.W.7. Price 8s. 6d.

Reinforcement of Rubbers. By D. Parkinson. The Institution of the Rubber Industry, 4, Kensington Palace Gardens, London, W.8. Price 25s.

Design in Structural Steel. Second edition. By John E. Lothers. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 56s.

Introduction to Thermodynamics and Heat Transfer. By David A. Mooney. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 40s.

Engineering Mechanics. Second edition. By Archie Higdon and William B. Stiles. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 32s. 6d.

Engineering Thermodynamics Work and Heat Transfer. By G. F. C. Rogers and Y. R. Mayhew. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 50s.

Newnes Electrical Pocket Book. Fourteenth edition. Edited by E. Molloy. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 10s. 6d.

Obituary

J. K. SHANKS

WE record with regret the death of Mr. James K. Shanks, which occurred on November 3 at Denny, Scotland. Mr. Shanks, who was eighty-seven, had been associated for sixty years with Cruikshank and Co., Ltd., having been managing director for thirty years and chairman of the company for the last eight years. Mr. Shanks received his engineering training on Clydeside, and spent some years at sea before beginning the long period of service which he spent with Denny and Co., Ltd. In his early days with the company he took an active part in the development of several marine and other engineering projects and, when he joined the Institute of Patentees in 1925, claimed to have made application for over forty patents, many of which had been completed. Another activity in which Mr. Shanks engaged was the development, during the first world war, of a number of high-duty iron and steel alloys for Admiralty and military use. In the 1920s, he began to build up the agricultural engineering side of his firm's business.

Mr. Shanks had been a member of the Institution of Engineers and Shipbuilders in Scotland and of the West of Scotland Association of Foremen Engineers and Draughtsmen for over fifty years. He also took a leading part in the civic life of Denny, serving as Provost of the Burgh from 1926 to 1932.

SIR WILLIAM FIRTH

SIR WILLIAM FIRTH, whose death, we regret to record, occurred in South Africa on November 11, had a prominent place in the activity of the Welsh tinplate industry prior to his retirement ten years ago. He was formerly chairman and managing director of Richard Thomas and Co., Ltd. Sir William, who was seventy-six, was born in London and entered the tinplate industry when he was twenty. A few years later he was managing the Grovesend group of works, which subsequently became part of the Richard Thomas organisation. In the later years of his active work in the steel industry, Sir William was closely concerned with the building of the Ebbw Vale plant, and it was the financial complications of this project which ultimately led to his resignation from Richard Thomas and Co., Ltd., in 1940.

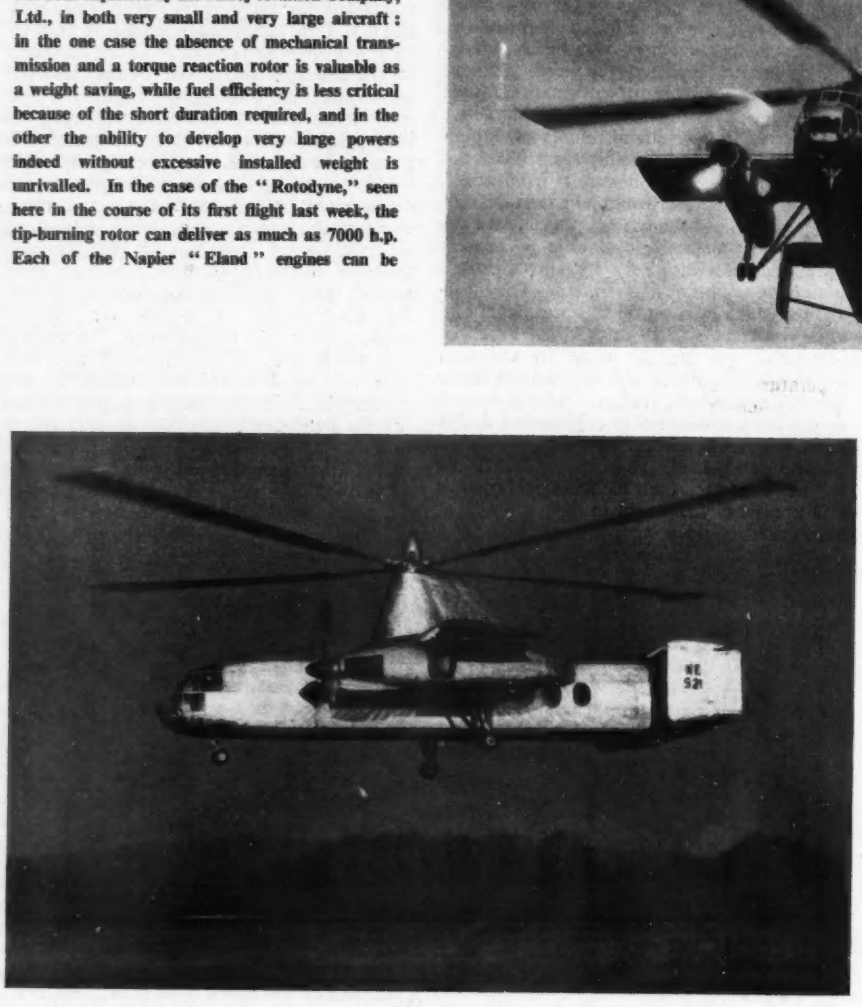
Among the many offices which Sir William held during his career were those of vice-president of the British Iron and Steel Federation, chairman of the International Tinplate Cartel, chairman of the Welsh Plate and Sheet Manufacturers' Association, and president of the Swansea Metal Exchange.

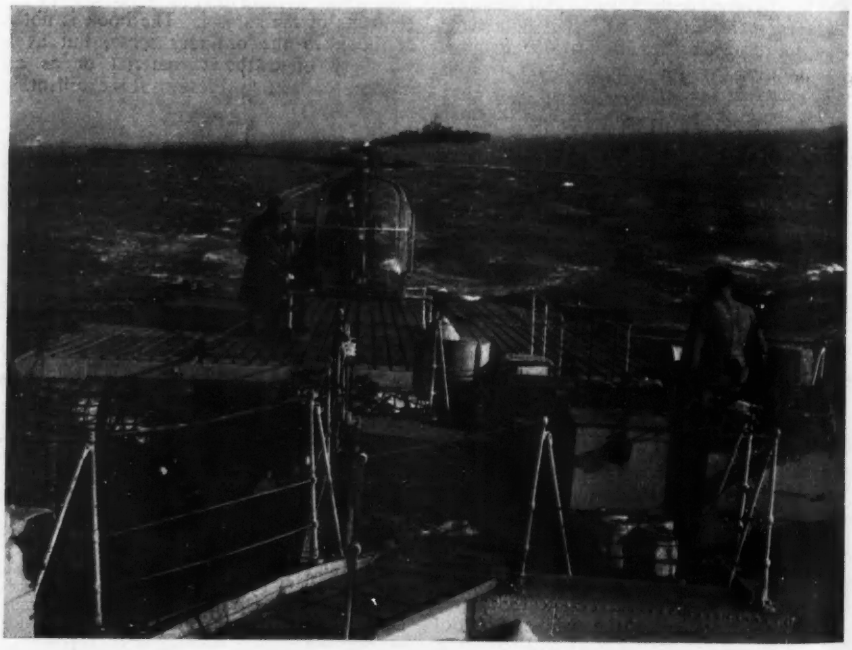
G. C. HODSDON

WE have learned with regret of the death of Mr. George Charles Hodsdon, which occurred recently, after a short illness at his home at Shepherds Lane, Dartford. Mr. Hodsdon joined the firm of J. and E. Hall, Ltd., Dartford, as an apprentice in 1887, and spent nearly the whole of his working life with that company. He became chief designer of J. and E. Hall, Ltd., in 1907, and in that capacity took a major part in the development of refrigerating machinery from the early days, first, with the cold air machines and CO_2 machines, and later machines using ammonia, and the Freon group. Mr. Hodsdon was elected an associate member of the Institution of Mechanical Engineers in 1901 and a full member in 1913. He was also an active member of the Institute of Refrigeration, on the council of which he served for many years.

Pressure Jet Rotor Craft

The principle of helicopter rotor drive by supplying air to burners at the blade tips and there burning it has been exploited by the Fairey Aviation Company, Ltd., in both very small and very large aircraft: in the one case the absence of mechanical transmission and a torque reaction rotor is valuable as a weight saving, while fuel efficiency is less critical because of the short duration required, and in the other the ability to develop very large powers indeed without excessive installed weight is unrivalled. In the case of the "Rotodyne," seen here in the course of its first flight last week, the tip-burning rotor can deliver as much as 7000 h.p. Each of the Napier "Eland" engines can be clutched, by means of a fluid coupling, to an air compressor feeding two blades of the rotor, so that an engine failure can only halve the power and does not call for response from the rotor fuel system to keep the burners alight. In cruising flight the couplings are drained and forward pitch applied to the airscrews; the rotor carries only half the weight of the machine, and the limitation on speed due to stall of the retreating blade is thereby raised. In the course of three flights from White Waltham the prototype ascended up to 250ft, flying at all times in the helicopter mode. It can be seen that the retractable undercarriage has been fitted with extra struts, which prevent the wheels deflecting under the weight of the aircraft; this is an interim measure until the problems of ground resonance have been studied. On the right the Ultra Light helicopter is seen on board the frigate H.M.S. "Grenville." Operating from a small platform above the quarter deck, the aircraft recently carried out more than seventy landings and take-offs. In rough weather in the English Channel, landings were made in winds of over 60 knots with the deck heaving 10ft to 12ft and rolling 14 deg. each way. The fine handling qualities which this helicopter has demonstrated are attributed in part to the use of power-operated controls





White Paper On Windscale

An accident occurred on No. 1 pile at the Windscale plutonium-producing plant just over a month ago. The resulting escape of radioactive iodine ed to the temporary suspension of milk distribution over a large area around the plant. A committee of inquiry was set up by the U.K. Atomic Energy Authority to investigate the cause of the accident and the measures taken to deal with it. With Sir William Penney in the chair, the committee consisted of Dr. B. F. J. Schonland, Professor J. M. Kay and Professor Jack Diamond. The Authority has submitted the committee's report to the Prime Minister, and an abbreviated version has now been issued in the form of a White Paper. We give here a brief account of the latter.

THE committee of inquiry set up to investigate the accident at Windscale on October 10 has reported and an abbreviated version of the findings has been issued as a White Paper (Cmnd. 302, price 1s. 3d.). The conclusion reached is that the accident was due both to inadequacies of instrumentation and to faults of judgment on the part of the operators, the faults of judgment indicating weaknesses of organisation. On the suggestion of the chairman of the U.K. Atomic Energy Authority, which accepts collective responsibility for the incident, the Prime Minister has asked Sir Alexander Fleck, chairman of Imperial Chemical Industries, Ltd., to advise remedies. Three committees have been appointed under Sir Alexander to study the matter and make recommendations.

The White Paper states that the accident occurred during a controlled release of stored "Wigner" energy from the graphite in No. 1 pile. That energy is stored in graphite under neutron bombardment has been known for some time, though information was scanty when the Windscale pile was built. According to the official history, Wigner energy was spontaneously released from No. 1 pile in September, 1952, during a shut-down, and the graphite suffered heating on that occasion without ill effect. This incident was studied and a standard procedure instituted for controlling the release of Wigner energy in the future. The procedure was to shut down the pile, arrange appropriate instruments, and then cause the pile to diverge without supplying cooling air. The temperatures of the uranium and the graphite would then rise, and a self-sustaining release of Wigner energy followed. Eight releases of this kind had been carried out on No. 1 pile by the end of 1956. In practice it was difficult to release evenly over all the graphite in the pile, and occasionally a second nuclear heating was found to be necessary some time after the first (the behaviour of the thermocouples in the graphite showed if release slowed locally, before all the graphite had been annealed).

The Accident

The committee of inquiry found that the immediate cause of the accident on October 10 was the second nuclear heating. Apparently this was applied too soon and too rapidly; it was thought by the operators that the release was dying away, and that parts of the graphite would fail to be annealed. Unfortunately, however, the instruments upon which this judgment was based were inadequate in number and distribution. Thermocouples were placed where the uranium was normally hottest, and not where the temperatures were highest during Wigner release. Also, the power meter read low under the conditions of the release, though it was correct for normal operation. "Acting on the observations which he had made," says the White Paper, "the Physicist in charge decided to boost the release with a second nuclear heating. He had no Pile Operating Manual, with special sections on Wigner release, to help him, nor had he had the benefit of sufficiently detailed instructions."

The pile diverged for the second heating on October 8. The maximum rate of rise of temperature was, for a few minutes, several times greater than normally permitted, but the maximum *recorded* temperature of the uranium was not higher than the normal maximum. The rapid rate of rise was observed, and the control rods were run in to reduce power, but, in the opinion of the committee of inquiry, one or more of the uranium cartridges in the lower front part of the pile had probably already failed.* The temperature of the graphite gradually rose on October 9, leading to the oxidation of the exposed uranium, the failure of other cartridges, and eventually the combustion of the graphite. The behaviour of the plant caused mounting suspicion on the part of the operators, and various prescribed measures were taken. By the afternoon of October 10 they had presumed that a cartridge had burst. The shut-down fans were started as a necessary preliminary to scanning for the site of the burst, but the gear was jammed. It was therefore decided to remove a plug in the charge wall at the front of the pile, and to view directly that channel the indicated temperature of which was the highest. The uranium cartridges were then seen to be red hot. By evening, the fire was affecting about 150 channels.

Distortion of the cartridges made discharge of the glowing channels so difficult that only partial success had been attained by the following morning. Carbon dioxide failed to quench the affected region. A fire break was created by discharging channels near to those that were red hot. The decision to make the use of water the last resort was reached at about midnight, but no other method of dealing with the situation had succeeded by seven in the morning. Shortly after this, therefore, all factory labour took cover, and the water was turned on. There was no immediate effect. An hour later the shut-down fans (kept running to make the attempted unloading operations on the charge hoist tolerable) were stopped. With continued pouring on of water the fire then subsided.

The uranium fuel cartridges in the lower front part of the pile, amounting to many hundreds of cartridges in all, had been there for some time. The uranium rods, therefore, had grown somewhat, by radiation damage, and some of the cans were in a state of strain. If the cartridges had been raised slowly in temperature only to the normal maximum operating temperature, by means of a nuclear heating, it is most unlikely that any would have failed. In all probability, one or more end caps of the cans of fuel elements were pushed off, and uranium exposed.

The White Paper closes its account of the mishap by saying that, in the opinion of the committee of inquiry, the steps taken to deal with the accident once it had been discovered were prompt and efficient, and displayed great devotion to duty on the part of all concerned.

* A second possibility, which the committee states that it was unable entirely to eliminate, is that it was a lithium-magnesium cartridge that failed.

Health and Safety

As requested by the Prime Minister, the Medical Research Council appointed an independent committee to report on the health and safety aspects of the accident. The report of this committee is reproduced in the White Paper. Its conclusions may be summarised as follows: (i) the information available is adequate to allow assessment of the possible risks to human health and safety; (ii) it is in the highest degree unlikely that any harm has been done to the health of anybody at all; (iii) the highest levels of radiostrontium in locally produced milk are well below those at which an appreciable hazard would arise, even if such milk were consumed for years, but a watch should be kept on milk from certain places; (iv) certain weaknesses in organisation were apparent after the event, notably delay between recognition of the danger and the institution of a suitable sampling programme. Certain gaps have been revealed in our scientific knowledge, and these require early attention; (v) the measures adopted by those responsible for the health and safety of the population were essentially right and, once brought fully into play, were adequate to prevent ill effects.

Calder Hall and Similar Reactors

The U.K. Atomic Energy Authority contributes a note to the White Paper in which it explains that the accident that happened at Windscale could not happen in the Calder Hall reactors or the reactors being built for the electricity authorities. Wigner releases will be required much less frequently (perhaps at five-year intervals), and when they do become necessary will present no hazard. This, says the note, is because: (*a*) The Windscale piles are air-cooled, but reactors of the Calder type are cooled by carbon dioxide. Self-sustaining oxidation of uranium occurs in still air at 350 deg. Cent.; the corresponding temperature with carbon dioxide is 650 deg. to 700 deg. Cent. (*b*) Cooling air is discharged from a high stack at Windscale, but the carbon dioxide coolant flows in a closed circuit in Calder reactors. The temperature of a Wigner release can be closely controlled by the main fans in a Calder system. (*c*) The scanner at Windscale is designed to move across the face of the pile and it jammed during the accident. The detectors at Calder Hall and in the electricity authority's stations are fixed, and each channel can be monitored without movement. (*d*) Fuel cartridges have been much improved and have a much lower rate of failure than at Windscale. (*e*) Instrumentation and control have also been much improved.

The note goes on to state that the graphite at Calder Hall is periodically checked for storage of Wigner energy, and additional safeguards can be introduced, such as an inert gas in the circuit during releases. Even if a fuel cartridge failed in a Calder reactor, detection would be immediate and the main fans would quickly reduce the temperature. The amount of radioactive material passing into the closed circuit would therefore be small, and leakages to atmosphere would be negligible.

Direct-Gas-Cooled Alternators

To meet the demand for alternators of 200MW and upwards, bearing in mind the weight limitations imposed by transport conditions in this country, electrical manufacturers are designing machines with direct cooling with gas or liquid coolants. The English Electric Company has developed a system using hydrogen gas, at pressures of 30 p.s.i.g. upwards, in direct contact with the stator and rotor conductors and the core. These principles have been embodied in a 100/120MW set which is destined for installation in the C.E.A. Willington power station. The development of such machines is briefly outlined here.

THE development of large alternators, with particular emphasis on direct-gas-cooling was the subject of a symposium held last week at the Stafford works of the English Electric Company, Ltd. Some of the problems that confront the alternator designer and builder in pursuing such developments were discussed at the symposium and, later, the participants toured parts of the company's works to see how these problems were being tackled.

While the economic case for the installation of very large turbo-alternators in fuel-fired steam power stations is well established, there are practical limitations on the output of a single set. The main limitations are imposed by size and weight. Any increase in size, for example, would bring into prominence such matters as the critical speeds of long rotors and differential thermal effects, particularly between copper and steel, and would increase the difficulty of making sound rotor forgings. In this country the physical size of the stator frame rules out rail transport and the effective limit is that of weight—150 to 160 tons imposed by the Ministry of Transport for carriage by road. The 100MW stators in the immediate post-war era approached this weight limit. Some increase in output could, indeed, be achieved by raising the pressure of the hydrogen coolant and by using a two-piece construction in which the core and windings were built and transported separately and were then erected in the main frame on site. But it was evident some years ago that a more fundamental change would be needed for the design of sets of 200MW and more.

For a given optimum speed and conductor arrangement the generated power is proportional to the current and the effective flux. A small gain can be made by using grain-oriented steel for the stator core but no substantial improvement can be expected from measures to increase the flux density. The only feasible method of reaching higher ratings is by raising the current loading in both the stator and the rotor and this uprating requires a much more effective method of removing heat than in the conventional machine. It can be done by direct cooling, in which the coolant is circulated in ducts or otherwise in contact with the conductor itself, instead of by the conventional methods which involve the abstracting of the I^2R losses through the thermal barrier of the conductor and slot insulation.

The overall gain is plotted in Fig. 1 which shows, to a base of hydrogen pressure, the current carrying capacities for a given temperature rise, of the stator and rotor windings when directly cooled as compared with conventionally cooled. These curves emphasise that gas pressure is much more important in direct-cooled machines in which the temperature rise of the copper is closely related to the temperature rise of the gas; whereas, in conventional machines the effectiveness of the cooling is strictly limited by the thermal gradient in the insulation.

Before considering how the principles of direct cooling may be applied in practice, it is perhaps useful to recall some of the indirect influences which the increased current loading will exert on the design. For example, there will be an increase in armature reaction ampere turns, and to counteract this effect additional reluctance will be required in the magnetic circuit: accordingly, the air gap is increased and for alternators of 120MW and upwards the radial gap is of the order of 3in to 5in. In the larger machines the sub-transient reactance is substantially increased (for example, 16 per cent at 200MW compared with 10·5 per cent at 100MW), which means that the forces on the conductor overhang at short circuit is reduced, as is the

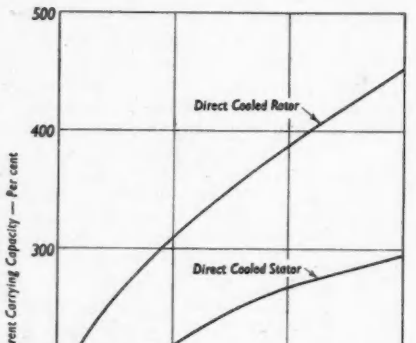


Fig. 1—The variation of current-carrying capacity with hydrogen pressure

short-circuit duty of the switchgear. On the other hand, the higher current loadings imply higher leakage fluxes, higher parasitic losses, higher local losses and some loss in overall efficiency. To assess some of these effects, about 300 thermocouples are rigged in the first full-scale direct-cooled machine (100MW) to go on test in the maker's Stafford works.

The general gain in power-to-weight ratio of alternators in recent years may be summarised in the statement that the weight per kVA of a direct-cooled alternator to-day is about one-third of a typical alternator at the end of the war.

Choice of Direct Cooling Method

The considerations that governed the choice of coolant, as expounded by English Electric engineers at the recent symposium, are summarised here.

Liquids, particularly water, are much better cooling media than gases and at first sight a liquid is the obvious choice. The application of water or oil to the cooling of the stator coils, while introducing complication, is quite practicable; but in the cases of the stator core and of the rotor winding, which is the most highly rated part of a machine, the problems are very formidable. Hence, for these latter components the use of hydrogen is at present necessary.

In the case of the stator winding the choice between liquid and gas can be decided on other considerations. Owing to the high voltage of the windings, it is impracticable to provide openings in the stator coils for the inlet and exit of the coolant other than at the ends so that the coolant flow path must extend at least over the full length of a coil side or of a number of coil sides in series. To employ liquid it is essential that the ducts are sufficiently robust to ensure that leakage cannot develop; in effect this means that some, or all, of the individual laminations going to make up the conductors have to be tubular in form. Furthermore, since the eddy current loss in a lamination is proportional to the fourth power of the depth the tubular lamination must necessarily be kept very small if the eddy current losses are to be held down to such a value that they do not result in a lowering of the machine efficiency. With very small sizes there is the risk that ducts may become blocked, and there are manufacturing problems both in the production of the tubes themselves and in their brazing to form the connections from coil to coil.

If gas is used, ducts can be formed from thin-walled material because there is no problem of leakage. Hence, they can be made of relatively large section and independent of the current-carrying strands. The pressure drop along such a coil side can be readily made equal to that required by the rotor, and by the stator core if it is also cooled by axial rather than by the more usual radial ducts. Thus, an overall ventilation system can be achieved which is very efficient in terms of both cooling and pumping power loss, particularly as only about a quarter of the gas circulation around the machine as a whole is required, compared with a conventional alternator of the same rating.

Because of the lower heat capacity of hydrogen compared with water or oil, the space factor of the gas-cooled coil is lower than of the liquid-cooled coil, and, therefore, some small reduction in overall core diameter and weight can be achieved by the use of a liquid. This possible gain is, however, relatively small unless the current density is increased to such an extent as to result in a significant reduction in the efficiency of the machine as a whole. Having found it possible to design for outputs up to at least 300MW without taking advantage of this gain, the English Electric Company has developed a completely gas-cooled design with the aim of keeping the machine as simple as is practicable.

While the self-fanning action of the rotor produces a certain circulation of gas, the differential pressure available from this source is small, and to obtain the benefit of the full potentiality of this system of cooling a very substantial pressure boost is essential. As has been said, the pressure requirements of the three main circuits of rotor and stator coils and of the stator core can readily be made the same, giving the maximum overall efficiency. The pressure required is, however, much higher than can be obtained from the hitherto normal axial flow fans on the rotor shaft and consideration therefore has to be given as to how this additional pressure may be obtained. Although the rate of gas circulation is low, the basic pressure of 30 lb per square inch gauge and upwards, together

with the high differential required, results in a pumping power which is significant in the total machine losses and it is therefore important that the maximum efficiency should be obtained from the blower.

If the blower were mounted on the main shaft the number of stages necessary would be large and the entry and exit conditions cramped and aerodynamically very inefficient. Further, the assembly of such a blower, and the provision for sufficient axial movement of the rotating blades to allow for thermal expansion effects in the main machine, would be difficult, apart from causing a substantial reduction in the first and second critical speeds of the alternator shaft due to the extra length required between bearings.

The company has therefore adopted a separate blower unit which is mounted in the upper part of the stator frame in the existing space between the two axially arranged coolers. In this position no increase in frame dimensions is necessary and a full diffuser can be incorporated on the blower outlet. The blower designer has freedom of choice as regards speed and number of stages. The drive is taken from an extra pinion on the exciter gearbox via a cardan shaft arrangement. A proprietary flexible coupling of stainless steel discs is incorporated and it includes a safety spline device to transmit the drive if the discs should fail.

120MW Direct-Gas-Cooled Alternator

A typical alternator with direct-gas cooling of the stator and rotor as described above is shown in sectional elevation in Fig. 2, in which the gas flow paths are indicated by arrows. The hot gas gives up its heat in coolers which are mounted (as with conventional hydrogen-cooled sets) in the stator frame. These coolers are not shown in Fig. 2 ; the nests of cooler tubes are arranged longitudinally and the rectangular apertures which give access to the tubes are roughly in the 10 o.c. and 2 o.c. positions in the stator end shield, as can be seen in Fig. 3. The blower is a four-stage, axial-flow compressor, with a design efficiency of 80 to 85 per cent running at 8300 or 7100 r.p.m.

Such a machine is the 120MW, 13·8kV, 0·8 p.f., which we saw on test during our tour of the English Electric works. This alternator is to be installed in the C.E.A. Willington power station.

Cross sections through the stator and rotor slots are shown in Fig. 6. In the stator winding the gas enters each half coil at one end of the alternator and leaves at the other, the gas ports being arranged in the end turns, as can be seen from Fig. 4. This method of cooling the stator winding is designed to give a reasonable pressure drop and to reduce to a minimum the differential thermal expansion between the two coil sides in a slot and between the coil and the core.

Referring to Fig. 6, the stator conductors are cooled by gas passing through the central stack of ducts, which are made of phosphor-bronze with a wall thickness of 0·012in. A special technique has been developed for bending the stack of ducts using a filler of low-melting-point alloy which is introduced as a liquid, then solidified by rapid quenching and, finally, after the bending operation, is melted by immersion in hot water. After the subsequent treatment which includes annealing and pressing, the bent coil stacks are free from any undue distortion or stresses produced by the preceding processes. Bends of 4in radius are practicable by this method, but the radius normally required is much larger. The gas tubes are insulated with a sleeve of glass fibre. The current-carrying stator conductors are transposed to equalise

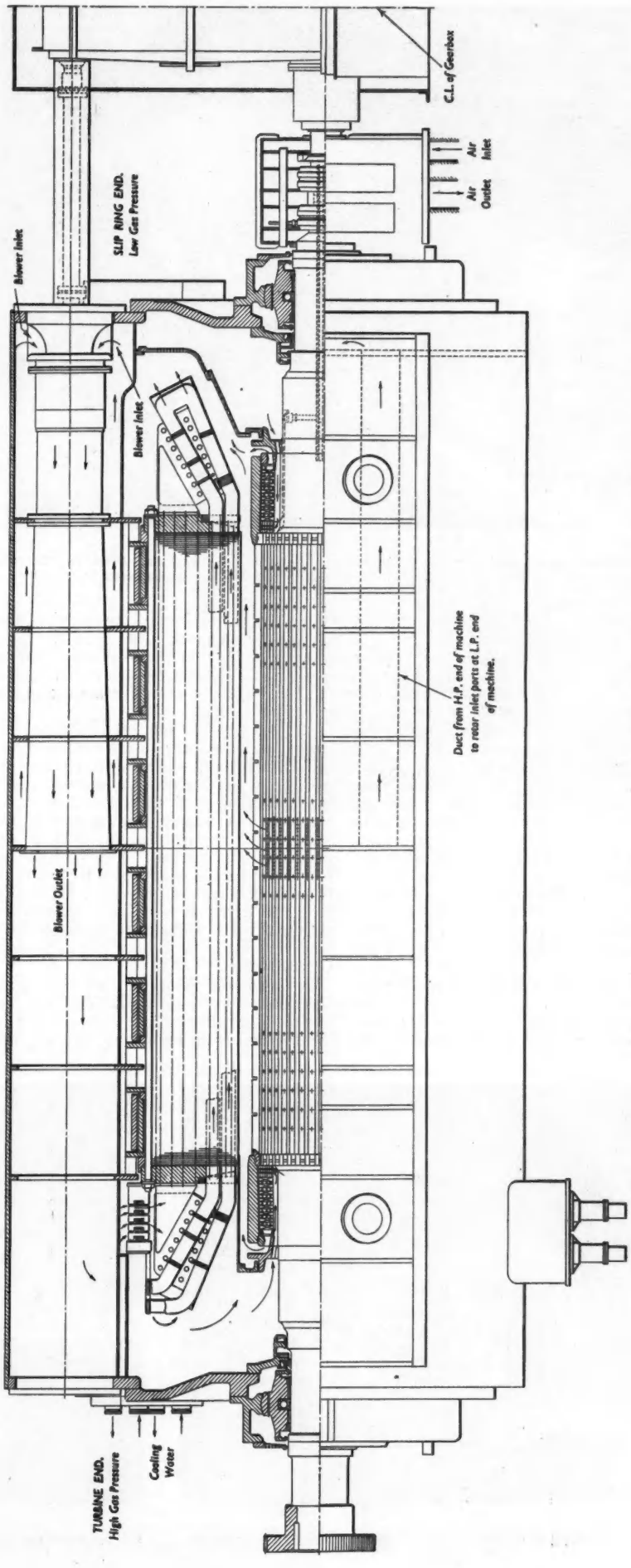

C.L. of Gearbox
Air Inlet
Air Outlet
SLIP RING END. Low Gas Pressure
Blower Inlet
Blower Inlet
Duct from H.P. end of machine to rotor inlet ports at L.P. end of machine.
Blower Outlet
TURBINE END. High Gas Pressure
Cooling Water

Fig. 2—Typical English Electric alternator with direct-gas-cooling of the stator and rotor. The flow paths of the gas coolant are shown by arrows

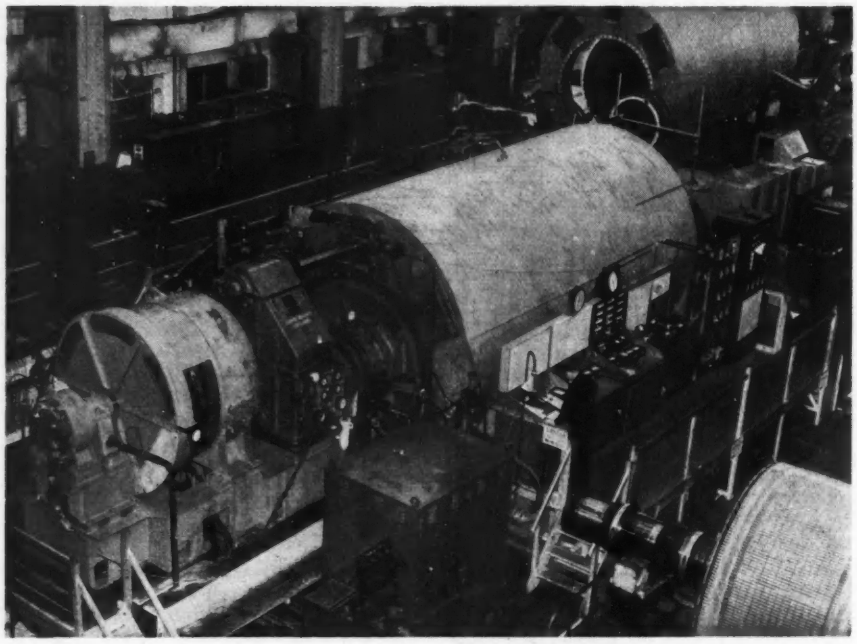


Fig. 3—Direct-gas-cooled alternator for Willington power station on works test. From left to right there are the pilot exciter, the main exciter, the gearbox and the alternator

current distribution. A brazed lap joint has been developed for the conductor strip.

For the cooling of the stator core circular ventilating holes are provided axially through the core and the requisite sealing at the end stampings is effected by a silicon rubber diaphragm. The gas circulation through these core cooling ducts is indicated in Fig. 2.

Separate paths are provided for the coolant gas in the end turns and the main conductors of the rotor windings. From the view of the rotor end windings reproduced in Fig. 5 it will be seen that the inlet and outlet ports for the gas in the end turns are in the side walls. This construction avoids the trouble that might otherwise arise from relative movement of the end turns which could cause partial restrictions in gas flow if the ducts were arranged radially through the conductor stack.

In the end face of the end turns the gas ports are circular. In the portion of the overhang near the rotor core the gas ports are rectangular as can be seen from Fig. 5. These ports are formed by piercing two rectangular tongues and pressing these tongues into the hollow conductors to form two separate guideways—one for the gas in the end turns, the other for the gas in the main conductors.

A special brazed joint was developed for the rotor conductors ; it can be seen at the top left of Fig. 5. Each pair of conductors, side-by-side, is joined by a shaped copper block, the ends of the conductors being staggered. A tongue forming part of the joint block overlaps the side wall of the conductor on each side. Viewed from the top, therefore, the joint is seen to be a combination of a butt and lap joint, the butting faces of the two conductor ends being staggered. The joints were made by resistance brazing with metallic electrodes and CO_2 capillaries.

By having the conductor ends staggered it was possible to obtain a good deal of information from ultrasonic tests carried out in the direction of the rotor axis. Not only was it practicable to discriminate between good and bad joints, but it was found that useful correlation could be established between the c.r.t. trace obtained in ultrasonic tests and the ultimate tensile strength of a joint (the value being about 3·5 tons in the case of a good joint).

In the overhang part of the rotor winding the adjacent turns are separated by resin-bonded asbestos spacers, as in Fig. 5.

This form of rotor is designed to carry excitation currents of 2000A to 3000A at

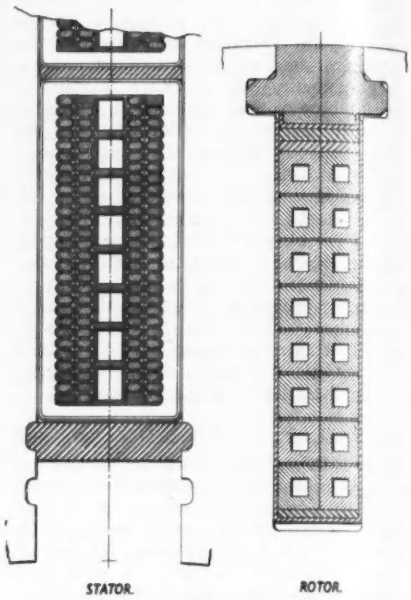


Fig. 6—Section through stator and rotor slots

600V. At the hottest part of the rotor, the centre, the temperature of the winding as measured by resistance methods, is stated to be less than in the case of a conventional machine.

The weight of this rotor is only 60 per cent of that of orthodox rotor of the same output and only slightly larger than a 30MW rotor of the immediate post-war era. In a 120MW machine the saving in weight attributable to direct-gas-cooling is less marked, say, 15 per cent, but the gain would be much more significant with 200MW or 250MW machines.

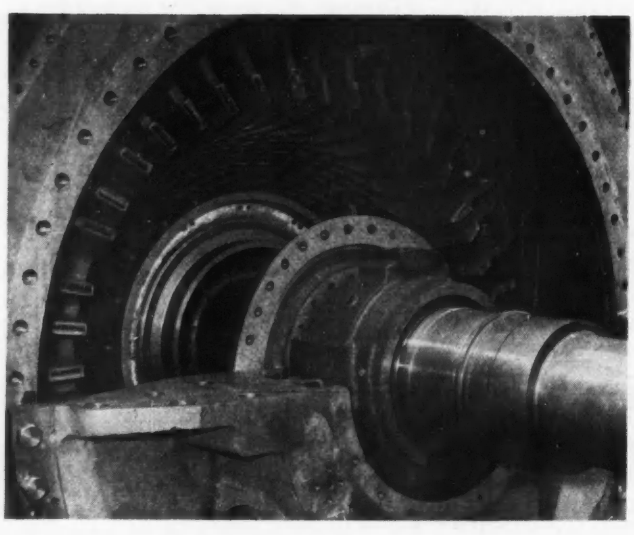


Fig. 4—Stator winding of direct-gas-cooled alternator showing gas ports in the end turns

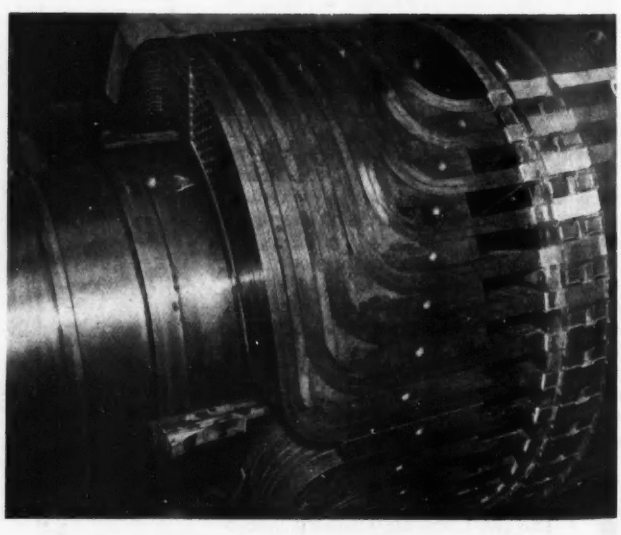


Fig. 5—Rotor end windings of direct-gas-cooled alternator. The gas ports and brazed joints can be seen

The terminal joints, specially developed for this class of machine, are brazed by high-frequency heating or gas ; they are tested ultrasonically and by pressure at 200 lb per square inch.

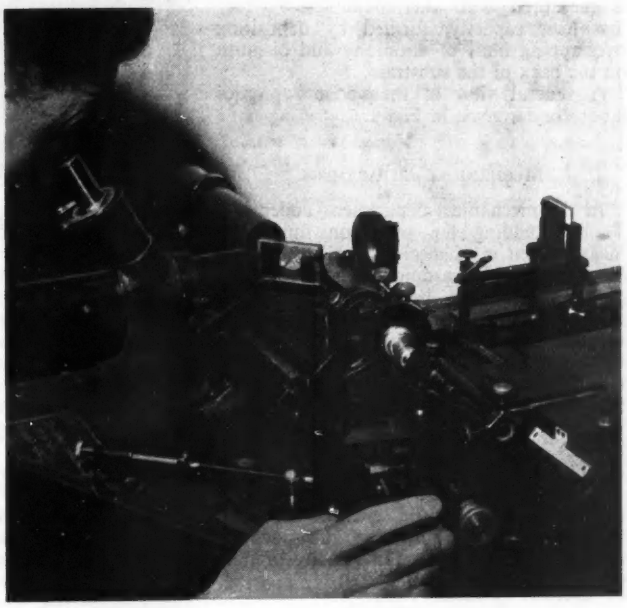
Two forms of special shaft seal to contain the hydrogen coolant have been developed with the help of the Napier company. One, a ring seal, depends upon the establishment of a differential pressure between the hydrogen and the oil which constitutes the sealing medium. Labyrinth glands reduce leakage of oil into the alternator and there is provision for removing the hydrogen entrained in the oil.

A face-seal has also been developed : it, too, uses oil as the sealing medium. It has been tested at 100 lb per square inch and 3600 r.p.m. Compared with the ring type seal the leakage of oil towards the hydrogen enclosure is greatly reduced. A similar kind of face-seal has been developed for the blower shaft.

As can be seen from Fig. 1, the gain in current carrying capacity from raising the hydrogen pressure is very considerable in the case of conductors which are direct cooled, and the trend is towards the use of pressures in excess of 30 p.s.i.g. To cater for these higher pressures it has been necessary to carry out development in connection with hydrogen shaft seals. A very extensive programme of work on these has been carried out, using a test rig on which full-size seals up to the largest diameter visualised have been tested, working with hydrogen up to pressures several times greater than the maximum so far employed. The rig shaft has been run with vibration amplitudes well in excess of those likely to be met with in service.

Scientific Instrument Research

The British Scientific Instrument Research Association (S.I.R.A.) started life in May, 1918, in Russell Square, London, with a founder membership of nine firms, which were mainly interested in optical instruments. In 1946 it moved to Elmstead Woods, near Chislehurst, Kent, and it now consists of 120 member firms. The S.I.R.A. establishment at Chislehurst has a staff of seventy-five, of whom thirty are graduates. Some of the research activities were seen during a recent visit to the establishment and are referred to below. The instrument illustrated here is a microscope interferometer for testing microscope object glasses.



THE British Scientific Instrument Research Association recently held a series of open days which gave visitors the opportunity of taking a look at its work. This Association, which is generally known as S.I.R.A., was founded in May, 1918, with an original membership of nine firms, seven of which were directly concerned with the making of optical instruments. For the first thirty years of its existence, S.I.R.A. was housed in Russell Square, London. Then, in 1946, the Association took over a large private residence at South Hill, Elmstead Woods, near Chislehurst, Kent, and in this building it set up a series of laboratories. Later an information department and library were established in a modern building in the same grounds. Another new building is now planned ; it will provide new laboratories (5000 square feet) for additional research staff.

In the thirty-nine years of its existence the membership of S.I.R.A. has grown from nine to 120 and its interests have broadened correspondingly. Whereas the founder members were mainly makers of optical instruments the present members have much more varied interests as a result of which the research work of the Association is divided into eight departments ; they are concerned, respectively, with physics, chemistry, electricity, electronics, mechanics, optics and photography.

About a third of S.I.R.A.'s experimental work can be classified as long-term research, aimed at the study of new technologies and ideas which may have a bearing on instrument manufacture. Initially, this class of work is pursued independently of its possible applications. Roughly the same fraction of the Association's experimental effort is concerned with applied research : the work may consist of short-term studies of a new technology or the investigation of previously untried methods of manufacture. Rarely, the development of a prototype instrument may be undertaken, but this kind of task is not normally within the scope of S.I.R.A.

Technical assistance is available to all members : it may consist of an experimental study, a survey of existing information or of a consultation. Some sponsored research can be undertaken : at the discretion of the director and subject to the approval of the D.S.I.R. a certain amount of confidential work can be done on behalf of individual member firms who would pay for this service and would have an exclusive interest in it.

Physics Laboratory

In the general section of the physics laboratory work is being done on methods of joining electrical leads to metal films on glass for use at high temperatures, such as may be used in resistance thermometers. For this purpose a method of attaching the conducting leads to the ends of a thin film is required which will enable the thermometer to be used at temperatures approaching the softening point of the glass. Terminals of silver foil are attached to the glass support by means of a silver paste which, when fired, adheres strongly to the glass and the foil and acts as a cement. The silver terminals overlap gold electrodes previously fired on to the glass, and the metal resistance element is deposited by thermal evaporation *in vacuo*, so that its ends also overlap the gold electrodes. The mechanical strength of the joint is such that even near the softening temperature of the glass failure occurs in the silver foil itself rather than at the joint.

High-Vacuum Laboratory.—A high-vacuum laboratory forms one section of the Physics Department, which is headed by Dr. K. M. Greenland. Here one of the research programmes is concerned with the production and measurement of atmospheres of very low humidities : porous ceramic transducers are used to measure atmospheric humidity in terms of electrical resistance. Such transducers remain sensitive in the region below 1 per cent relative humidity. A simple instrument, calibrated from 0 to 1 per cent relative humidity, has been developed in this laboratory. In this apparatus atmospheres of known humidities are produced by dividing dry air (dew point about −70 deg. Cent.) into two streams by a proportioning valve, saturating one stream and then recombining it with the other. The resulting relative humidity is calculated from measurements of the rate of flow of the wet and dry streams.

Apparatus has also been developed for the control of film thickness in the vacuum evaporation process. In the making of narrow-band (Fabry-Perot) interference filters the thickness of the dielectric film separating the two metallic films must be controlled with accuracy if the mean wavelengths of the transmission bands are specified. The optical system devised for this task provides a measure of the thickness of the dielectric film as it is being deposited : interference is induced by multiple internal reflections within the film and this interference results in the appearance of a narrow absorption band in the spectrum of white ligh

reflected by the film. The wavelength of the absorption band is measured with a spectroscope and the thickness of the film is then read on a calibration curve.

Another experiment in the vacuum laboratory concerns the measurement of heat of adsorption of metal films on a silica substrate, using thin film thermocouples. This experiment represents one aspect of the work on the mechanism of adhesion of thin films to their substrates, which is a major subject of investigation in the research project concerned with thin films. The aim of this experiment is to compare the release of energy when various films are formed by condensation *in vacuo*. The rise in temperature of the substrate during condensation is measured with thermocouples of very low heat capacity, formed by depositing overlapping films of antimony and bismuth on the back of the substrate.

A general view of the vacuum physics laboratory is given in Fig. 1.

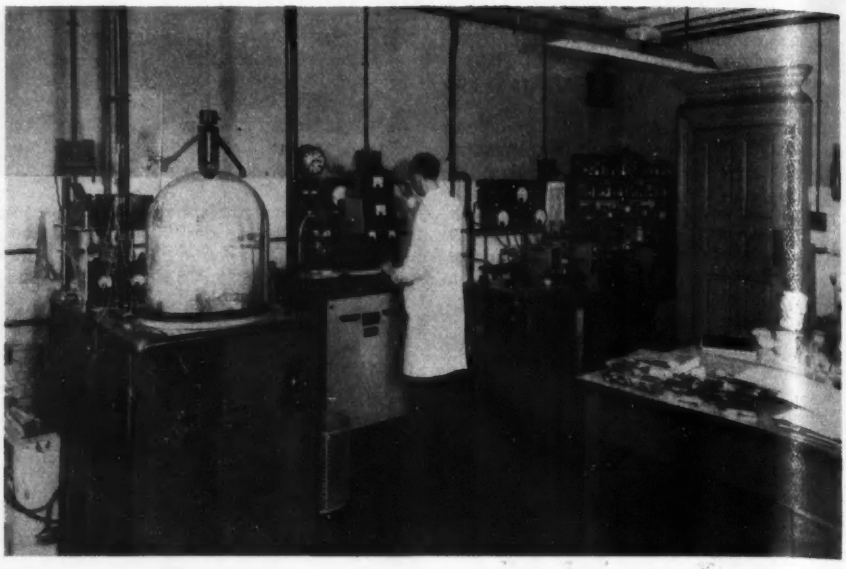


Fig. 1—Vacuum physics laboratory. Progress has been made here in the development of methods of controlling film thickness in the vacuum evaporation process

Mechanical Department

In the mechanical department under Mr. T. H. Redding the work on fluid flow measurement is of special interest. Electromagnetic and ultrasonic methods of flow measurement have been developed. The electromagnetic flowmeter is characterised by the fact that it measures average flow over the cross-section of the pipe and that the two simple electrodes offer no obstruction to the flow. The flowmeter is based on the well-known principle that a potential difference is developed between the ends of a conductor moving across a magnetic field. In this particular instrument the conductor is represented by the element of fluid between the electrodes and the potential difference is related to the velocity of fluid flow by the expression

$$e = Bdv\ 10^{-8} \text{ volts},$$

where

B = magnetic field strength, gauss,
d = diameter of pipe, cm,
v = velocity of flow, cm per sec.

The voltage e is amplified and measured and the instrument is calibrated (Fig 2) to give direct measurements of flow. Although the conductivity of the fluid is not at first sight involved in the measurement, it is important that the impedance of the measuring device should be many times greater than that of the source, that is, the fluid between the electrodes. This condition limits the range of fluids with which the electromagnetic flowmeter has been used.

The model that we saw on our visit is suitable for operation with water and with ethylene glycol.

The ultrasonic flowmeter has applications where obstruction to flow is not permissible, and in situations where isolation of the measuring elements from the fluid is essential. This instrument measures the transit time of ultrasonic waves between two points in a pipe to indicate the rate of flow of fluid in the pipe.

If the ultrasonic wave is propagated at a velocity of c cm/sec. between transducers d cm apart in a fluid flowing at v cm per second in the direction of propagation then the time of transit is $d/(c+v)$ secs. In the S.I.R.A. flowmeter a wave is also propagated against the flow and the differential time is measured as a phase difference between the signals at the receiving transducers. This model has been designed to give a full-scale reading in the region of 20 gallons per minute in a 2in pipe. The system can readily be adapted to other pipe diameters and velocity ranges.

Work on the grinding of glass is also in hand in the mechanical department, the object being to produce finely ground surfaces of accurate contour, so that the time required for the subsequent polishing processes may be reduced.

A conventional lens generator using bonded diamond tools has been modified for this work to operate at high speeds with a light and carefully controlled pressure between the tool and the work. To reduce vibration a hydraulic motor is used to drive the grinding spindle and hydraulic transmission is used for the work feed. We learn that by these devices the laboratory has produced ground surfaces of very fine texture, without deep pits and with only a very small depth of flawed material below the abraded surface.

In later developments of this work the ground surfaces have been examined by interferometry and experiments have been done to determine the performance of expendable ceramic tools in the final grinding operation.

Electronics Department

Two new designs of drift-corrected d.c. amplifiers have been developed in the electronics department under Mr. R. E. Fischbacher. The first uses a cascade-balance system in which the zero level variations in the first stage caused by supply voltage and temperature fluctuations are balanced against those in the second stage, instead of the variations being balanced between valves in a stage as is usual. An essential part of the system is the application of the Owen-Prinz drift-correction principle to the first stage, which is duplicated to preserve bandwidth.

The single-sided nature of the amplifier enables negative feedback to be applied, but the outstanding advantage over the parallel balance amplifier is the relative reduction in zero variations by a factor of over 100,

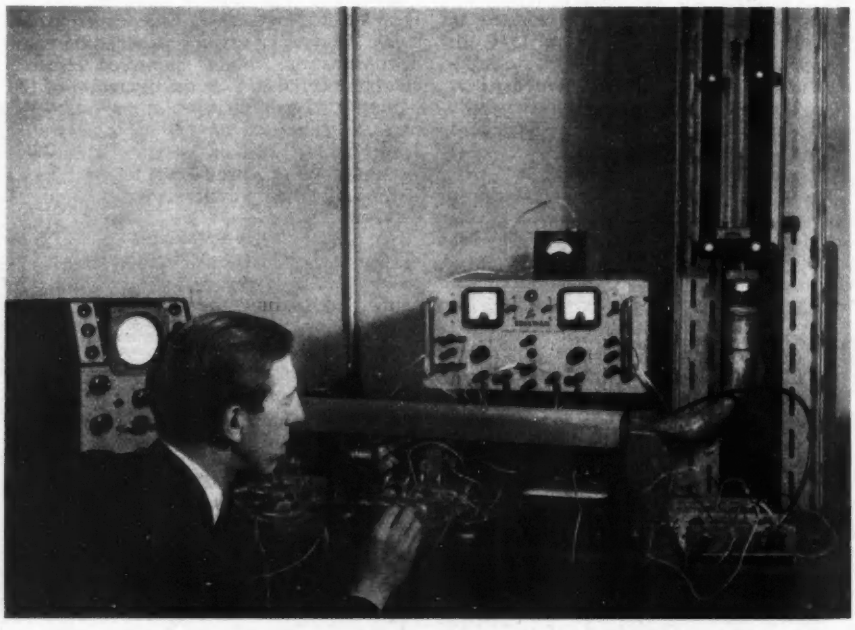


Fig. 2—Using a " Rotameter " to calibrate the S.I.R.A. electromagnetic flowmeter

rendering stabilised supplies redundant. Incidental merits of the amplifier are a very high input resistance and a frequency response level to 25 kc/s. The amplifier consists of three identical stages of gain μ. The first two stages serve alternately as the first amplifying stage, with a slight overlap period to preserve continuity. While each stage is out of service its drift is corrected by the Owen-Prinz capacitor storage method ; this correction reduces the drift in the first stage by a factor $(\mu+1)$, so that the residual drift is comparable but opposite in effect to that in the second stage and interstage balancing becomes possible.

The second design of amplifier is an embodiment of the reflex monitor system, in which the cascade-balance principle is revised and applied in a direct-coupled amplifier using overall drift correction. Contrary to normal practice the correcting amplifier or monitor is not inherently drift free, but is itself direct coupled and is a replica of the first stage of the main amplifier ; it corrects, alternately, its own drift by the Owen-Prinz method and the drift of the main amplifier. The residual effects of supply voltage and temperature fluctuations are balanced between the two amplifiers, which are effectively in cascade during the overall correction phase.

Whereas the simple cascade-balance system is best suited to amplifiers with a single-ended input, this later development automatically provides for a differential input with a very high rejection factor against in-phase components. The performance capabilities are similar, with an overall zero stability of 0·1mV obtained without recourse to stabilised supplies.

The main amplifier comprises stages which need not be similar. The second is the correcting amplifier and is identical to the first stage. It alternates between two conditions : in the first its own drift is checked and corrected by the Owen-Prinz capacitor storage method ; in the second it is used to compare the input signal with a suitable fraction of the output signal and, interpreting any discrepancy as drift in the main amplifier, causes a correcting potential to be applied on a capacitor. Residual drift errors in the two amplifiers are similar in effect, and with the connections suitably sensed are opposing.

The electronics laboratory is also developing a photo-electric indexing servo-mechanism. It is designed for the kind of problem where some operation, such as the ruling of graduation marks, drilling or other machining, is to be performed on a piece of work in each of a number of predetermined positions, regularly or irregularly spaced. The mechanism, controlled by optical signals from a master plate, carries out the threefold task of (*a*) locating the work accurately in its first desired position, (*b*) initiating the operation to be performed in this position, (*c*) sensing the completion of the operation and driving the work towards the next position ; this cycle is repeated automatically as often as desired. Circular or linear motion of the work can be equally well arranged. In the demonstration seen for the open days the machine tool operation was symbolised by a motor-driven pen which traced a line on a record chart, representing the work, in each of the desired positions. The accuracy of positioning is said to be of the order of 3/10,000in.

Electrical Department

The design and performance of low-power magnetic amplifiers have been the subject of special studies in the electrical department under Dr. A. J. Maddock. The work has been concerned mainly with series-connected magnetic amplifiers on a 50 c/s supply. The main causes of zero drift in balanced magnetic amplifiers and the precautions necessary to minimise them have been examined. Response time, stability of gain and the effects of several forms of feedback has been investigated. A design method for magnetic amplifiers, which takes into account reverse current of the rectifiers, has been included in the study.

It is concluded that the lowest zero drift which can be fairly readily achieved is equivalent to an input signal of 10^{-11}W. This value corresponds to about 30μV or 0·3μA for an input winding of 100 ohms resistance. These figures relate to 100 hours of test with supply voltage variations from +5 per cent to −10 per cent, supply frequency variations from − 4 per cent to +2 per cent and temperature variations from 5 deg. to 30 deg. Cent.

The magnetic amplifier exhibited operates within these limits for zero drift, and was shown with a thermocouple input. An input of 4mV from the thermocouple corresponding to a temperature difference of 100 deg. Cent., gives an output of 5mA into 500 ohms, suitable for direct operation of a recording milliammeter. The power gain is 400,000. The zero drift expressed in terms of temperature indication is just over 1 deg. Cent.

Constant current sources of direct current using transductors are also being developed for use in instances where it is necessary to stabilise d.c. supplies of several hundred milliamperes to several amperes at voltages of up to about 20V. Typical applications include stable supplies for valve heaters, for lamps in photometric work and for electromagnetic fields ; the simple transductor, fed with a small constant current on a reference winding, has proved very useful for such applications. A constant current output is obtained. The resistance of leads is of little importance with this kind of output, switching-on surges are almost eliminated, and the source may be short circuited with impunity. The reference current may be obtained from a pentode stabilised by a voltage reference tube. The improvement on supply voltage variations ranges between 50 and 100 to 1. Recovery time is about 1/5 seconds. Four typical designs which have been made in the laboratory have the following ratings :— (1) 0·9A, 12V, for valve heaters ; (2) 2A, 12V, for a lamp ; (3) 10A, 1V, for an infra-red source ; (4) 18A, 6V, for an ultra-violet source. The output currents and load resistances may be varied over a fairly wide range.

In one of two general laboratories work is being done on the behaviour of some low-pressure electrical contacts. The studies have been of point-to-plane contacts, operating at loadings less than a few milligrammes and into the microgramme region; they are made either of platinum-gold-silver alloy or of fine gold. A relationship has been established between the dust concentration in the atmosphere and the number of likely failures to make contact. Dust can have a big influence on the behaviour of the contacts at these light loadings. The variation of contact resistance over the operating force range of 0–4000μg. shows that the resistance rises rapidly and to extremely high values below 1000μg.

Workshop

Various engineering services required in common by the various laboratories are provided by the workshop. Here, during our visit, we saw demonstrated a process of electro-plating with a damp pad and without an electrolytic bath. In this process, which is of French origin, very little plating solution is required ; it is applied by a pad to the work, which is clipped to the cathode lead of a power pack giving a d.c. output up to 15A to 40A at 35V. An air-cooled graphite electrode constitutes the anode. This process is particularly useful for depositing films of precious metals, for plating restricted areas without the need for masking, for building up worn surfaces and for applying small areas of plating to instrument assemblies.

An ingenious instrument developed in the workshop is a micrometer with a pneumatic sensing device. This combination of a mechanical micrometer with an air gauging circuit provides a method of gauging without contact.

Silicon Semi-Conductor Factory

A new factory for the manufacture of silicon transistors and rectifiers was opened recently at Bedford. It is the first manufacturing plant of Texas Instruments, Ltd., a British subsidiary of Texas Instruments Incorporated, of Dallas, Texas.

Initially the British firm is concentrating on the production of silicon semi-conductor devices which can be used in industrial equipments where the temperature conditions militate against the use of germanium. Although the British company is self-contained, its production is backed by the basic research and technical knowledge that is provided by the parent company in the U.S.A. The first phase of development in the British factory consists of separate production lines for medium power devices, high-frequency tetrodes and rectifiers. The subsequent programme, which is due to be completed by the end of this year, includes the introduction of a second rectifier production line and a line of 37·5W power transistors.* Texas silicon rectifiers now in production have ratings of 400mA and 750mA with peak inverse voltages ranging from 200V to 600V. Rectifiers designed for current ratings up to 5A and similar peak inverse voltages are due to be introduced in the very near future.

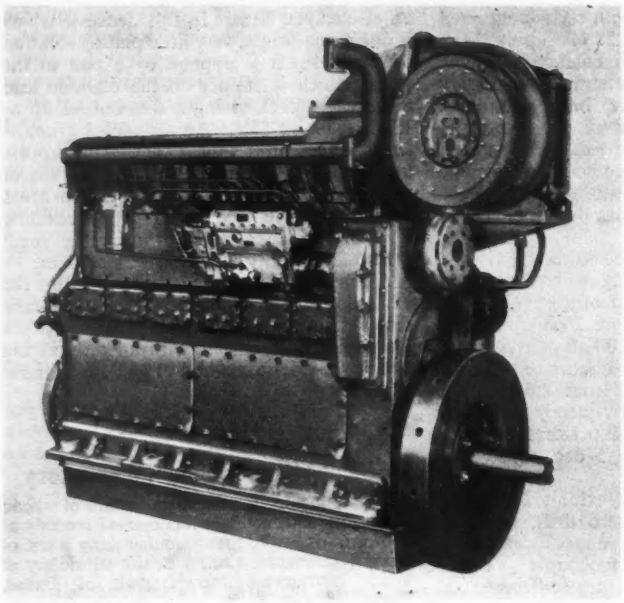
Another product soon to be available is a high-frequency tetrode which is designed to enable amplifiers to operate at frequencies up to 30 Mc/s. Development work is stated to be well advanced on silicon rectifier equipments with current ratings that are sufficiently high to widen the scope of these devices on the power side to electric traction and welding.

Technical Reports

Etude de la Convection par les Fils aux Faibles Nombres de Reynolds. By J. Gosse. Publications Scientifiques et Techniques du Ministère de l'Air, No. 322. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price Ffr. 1200.—Most of the work concerning the heat transfer from cylindrical surfaces to a liquid was based on dimensional analysis and covered a range of Reynolds numbers from 1000 to 500,000. The results are in good agreement and no further developments can be expected. The same cannot be said of lower Reynolds numbers where natural convection and end effects influence the result. This is a region which has been somewhat neglected by experimenters. The author has carried out a careful study, using platinum wires, of the heat transfer under conditions of laminar flow. He describes several aerodynamic regimes with their corresponding thermal regimes, which are defined by different values of the Reynolds number. Finally, the effects of turbulence caused by using wire meshes were examined.

Uses of Radioisotopes in the Textile Industry : a Selected Bibliography. By L. L. Covert. Report No. 54, Technical Information Service, National Research Council, Ottawa, Canada.—First prepared in response to a specific request, this bibliography of twenty-one references is now published because of its general interest.

* The dissipation of this power transistor is specified as 37·5W at 25 deg. Cent. and 15W at 100 deg. Cent.



Medium-Power Vertical and Horizontal Oil Engines

A new range of six and eight-cylinder vertical and horizontal oil engines of medium power has been designed by the National Gas and Oil Engine Company, Ltd.; our first illustration is of a vertical, six-cylinder, turbo-charged engine, Mark N.M.S.6, which develops 360 b.h.p. at 1500 r.p.m. A free-piston gasifier is also described and illustrated.

WE recently visited the works of the National Gas and Oil Engine Company, Ltd., at Ashton-under-Lyne, to see several models of the new N.M. series of oil engines on test. This series of engines has been designed by the company to meet the power range demanded by modern requirements and was introduced at the Engineering and Marine Exhibition, held in London, when a horizontal model was on view and briefly described in our issue of August 30. In addition to seeing the new oil engines the opportunity was taken to inspect a G.S.34 free-piston gasifier, which is undergoing trials, and which the company build under licence for certain applications.

The N.M. range of engines has undergone a proving period of two years and is now in production as six or eight-cylinder units, in both vertical and horizontal versions. These compression-ignition, four-stroke engines have a bore of 6in by a stroke of 8½in, and are available as normally aspirated, mechanically supercharged, turbo-charged and high-pressure turbo-charged, with after-cooler for vertical, units and designated NM, NMB, NMS and NMSS respectively. A vertical, six-cylinder, turbo-charged engine, Mark NMS6, is illustrated above. The horizontal version, which is intended primarily for railcar services and where headroom is limited, is only available normally aspirated or mechanically supercharged. In normally aspirated form the compression ratio is 15 to 1, and is 13 to 1 in the supercharged range, while the mechanical efficiency is stated to be 80 per cent when normally aspirated or mechanically supercharged and 86 per cent when turbo-supercharged.

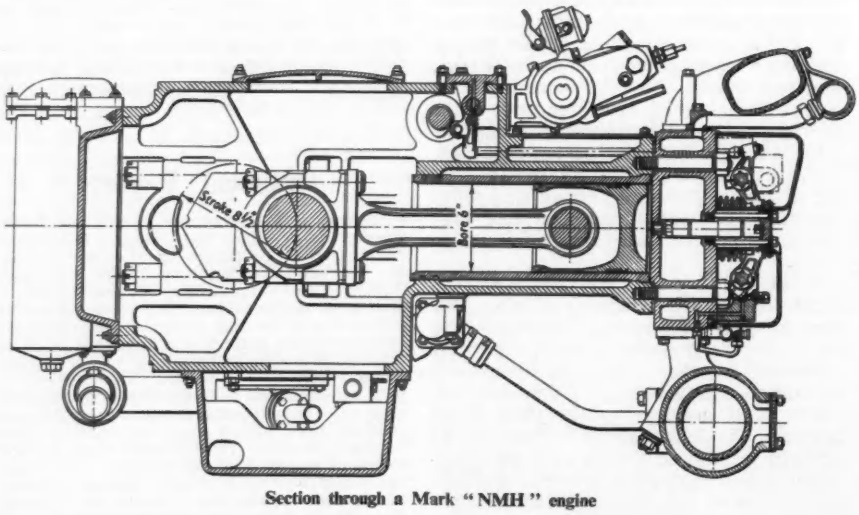
The power range covered by the engines is set out in the following table, which indicates that the continuous brake horsepower developed by the normally aspirated and mechanically blown engines is from 164 to 438 b.h.p. For the turbo-charged engines the power range is from 240 to 533 b.h.p., with the possibility of particular purpose engines being run at 1800 r.p.m., giving a power range of from 400 h.p. to 600 h.p.

The brake mean effective pressure increases from 90 lb per square inch in the normally aspirated unit to 120 lb per square inch in the mechanically blown engine, while the brake mean effective pressure in the turbo-charged models is 132 lb and 146 lb per square inch respectively.

The engines are designed to use light diesel and gas oils of 19,000 B.Th.U calorific value and a viscosity not more than 45 seconds Redwood No. 1 at 100 deg. Fah., and the fuel consumptions at 1500 r.p.m. are given in the accompanying table :—

Consumptions per Brake Horsepower per Hour

Engine Mark	Full load		Three-quarter load		Half load	
	Lb	Gm	Lb	Gm	Lb	Gm
NM	0·385	175	0·39	177	0·44	200
NMB... ...	0·42	191	0·42	191	0·45	205
NMS... ...	0·375	170	0·385	175	0·41	186
NMSS ...	0·375	170	0·375	170	0·40	182

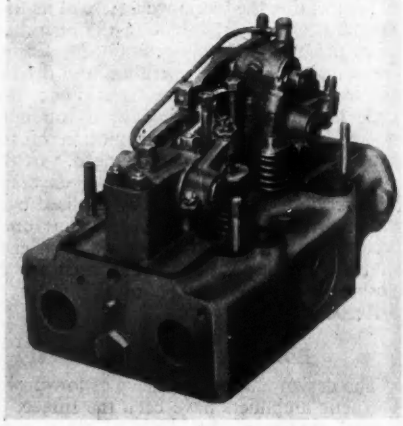


Section through a Mark "NMH" engine

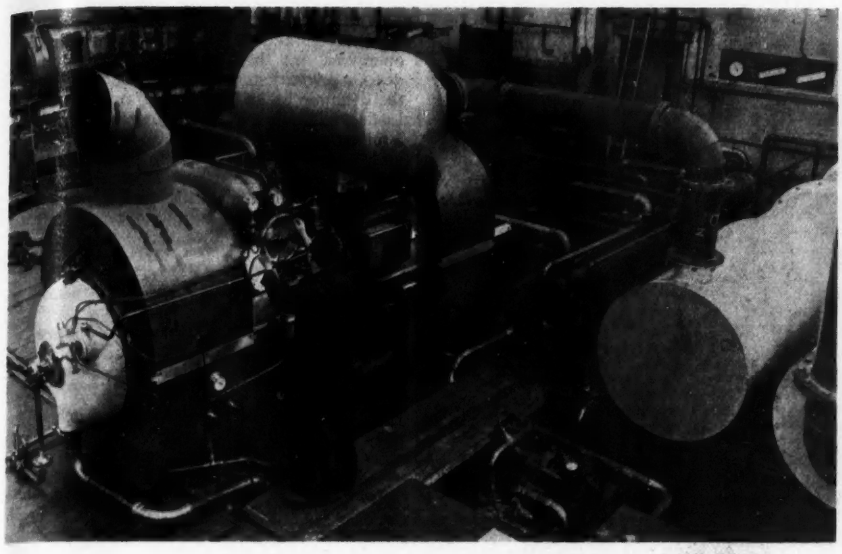
Continuous Brake Horsepower

Engine Mark	No. of cylinders	Revolutions per minute			
		1000	1200	1500	1800
NM6	6	164	196	246	—
NM8	8	219	263	328	—
NMB6	6	219	263	328	—
NMB8	8	292	350	438	—
NMS6	6	240	288	360	400
NMS8	8	320	384	480	534
NMSS6...	6	267	320	400	450
NMSS8...	8	355	426	533	600

This new engine series, of which we include a line drawing of a cross section of a Mark NMH6 unit, has the same bore and stroke as the well-known M4A engines, built by the company, and many parts are common to both series. Cast iron is used for the crankcase and the cylinder heads, illustrated herewith, which have two inlet and two exhaust valves arranged in pairs on opposite sides and operated from a single camshaft. Copper-



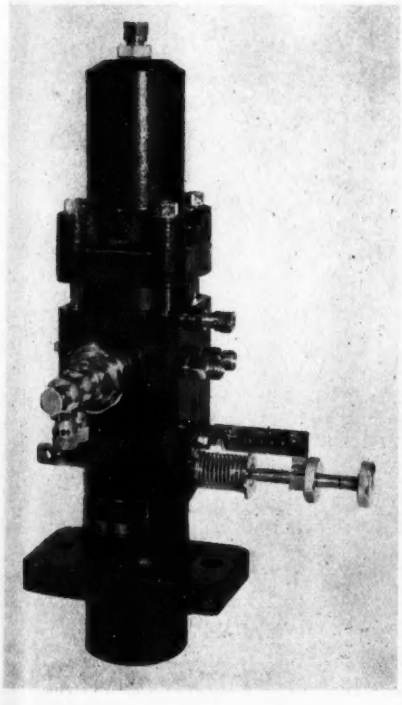
Four valve cylinder head of N.M. engines



"GS/34" free piston gasifier undergoing shop trials

lead shell underslung bearings carry the hardened and heat-treated alloy steel crankshaft, and the aluminium alloy pistons are fitted with three compression and two scraper rings. Wet cylinder liners with chrome-hardened bores are employed. A solid injection fuel system is incorporated, and the fuel is delivered through externally mounted piping from a monobloc gear driven pump fitted with a lift pump and a hydraulic governor. A gear pump circulates the lubricating oil; the cooling water passes through the jackets, and then part goes through the cylinder heads and the remainder through the exhaust manifold. Starting is by electric motor or by compressed air.

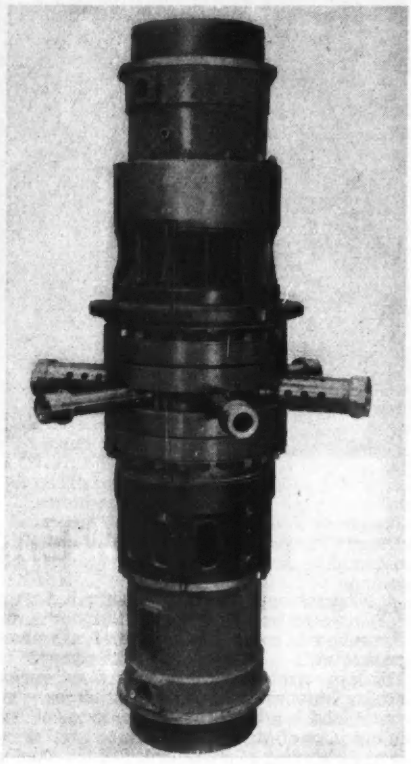
Since obtaining a licence to build free-piston gasifiers the National Gas and Oil Engine Company, Ltd., has been engaged in assembling the necessary tools, in preparation for going into production. That part of the work is complete and the first unit, illustrated herewith, has been undergoing shop trials, while construction is proceeding on a number of gasifiers which are on order. The gasifier has a cylinder diameter of 340mm, a compressor cylinder of 900mm diameter and a stroke of 400mm to 500mm. Speed varies from 350 to 600 cycles per minute and the gas pressure and temperature is 43 lb per square inch gauge and 825 deg. Fah. respectively, while the unit has a continuous rating of 1250 gas horsepower, which is equivalent to approximately 1000 b.h.p. A brief report on the progress made by the company in the construction of the G.S.34 appeared in our issue of August 9, and descriptions of the engine for which Alan Muntz and Co., Ltd., hold the licence, and its applications have appeared in THE ENGINEER on March 6, 1953, January 22, 1954, and June 1, 1956. Starting is by compressed air, a volume equal to 70 cubic feet of free air being required per start, and the gasifier can operate on a wide variety of fuels, including heavy fuels.



Accumulator pattern fuel injection pump for "GS/34" gasifier

The fuel injection equipment has been built by Bryce Berger, Ltd., to S.E.M.E. design and S.I.G.M.A. development, and includes an accumulator pump, two "T" size injectors and four "U" size injectors. Since the fuel is injected over a period including the inner dead centre, when the pistons and connecting parts have momentarily stopped, the fuel has to be metered prior to injection and stored under pressure in an accumulator. A compressed air piston regulates the duration of the injection. Our illustration shows the fuel injection pump, in which the metering pump plunger is driven by one of the piston synchronising connections and the quantity controlled by a helix ground in the pump plunger, the angular position of which is controlled by a rack. The metered fuel is delivered through a non-return valve arranged centrally in a larger valve below the accumulator piston, which is loaded by a compressed air piston to give the required injection pressure. Shortly before the end of the stroke the pump plunger lifts the spring-loaded valve and the fuel is delivered through pipes to the injectors. At each working stroke the fuel is delivered into the disc-shaped combustion chamber between the two pistons through four "U" size and two "T" size injectors arranged uniformly around the circumference, as seen in our illustration, which shows the engine cylinder assembly. The former are direct injectors, and the latter, sited opposite each other, inject into precombustion chambers to produce additional swirl in the main chamber by means of hot air jets.

For use with the free piston gasifiers the

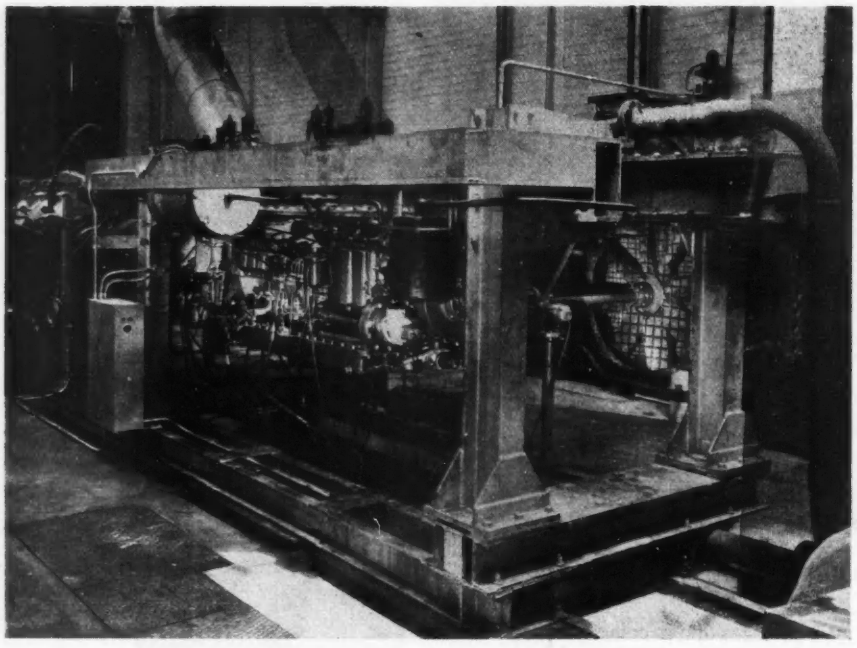


"GS/34" cylinder assembly

Brush Electrical Engineering Company, Ltd., has designed a range of gas turbines having a nominal power rising from 1000 h.p. to 10,000 h.p. with a difference of 1000 h.p. for each frame size. A fuel consumption of 0·386 lb per horsepower per hour at the turbine shaft has been recorded for 2000 h.p. sets, and it is estimated that a 6000 s.h.p. marine set, including gasifier, turbine and gearing will have a weight of 35 lb per shaft horsepower, and cost less than diesel machinery of the same power.

SUPPORTING SKIRTS FOR REACTOR PRESSURE VESSELS.—In THE ENGINEER of August 23 last, we published an article with the above title written by Dr. R. Hicks. Two errors occurred in the mathematical expressions in the article, as follows. At the top of the third column on page 256 there is an equation for a moment M_{TT}: the denominator of the first group of terms on the right-hand side of the equation should be $4\beta^3$ and not $4\beta^4$ as stated. In the centre column of page 257 there is a definition of the constant λ; this definition relates to λ^4 and not λ^3 as stated.

BUNSEN BURNER FOR HIGH CALORIFIC VALUE GASES.—The greatly increased use being made, both in this country and abroad, of propane/butane, methane/natural gas and sludge gas in laboratories where town gas supplies are not readily available, has prompted Amal, Ltd., of Witton, Birmingham, to market a new bunsen burner, known as the "3 Jet Maximus." This burner gives a carpet of small blue cones over the surface of the 2¾in diameter head, the area of which is sufficient for the heat to be distributed evenly under large diameter flasks. It has been designed to permit the passage of the greater volume of primary air required with high calorific value gases to give the same heat output as a smaller standard town gas burner. A finger-controlled needle valve in the gas supply line in combination with the grid burner head gives flexibility in pressure control with good turn down and the use of the three precision jets also contributes to the "carpet" flame characteristic.



Railcar Engine Test Bed

AN interesting test bed has been installed at the Crewe works of Rolls-Royce, Ltd., for development work in connection with the firm's railcar power units. These units each comprise a 238 h.p., eight-cylinder, horizontal oil engine driving through a hydro-kinetic torque converter, and brief particulars were given of one in our issue of May 17 last. The test bed simulates the loading of a unit under all the running conditions likely to be encountered by a railcar in normal service. It consists of a mounting structure representing a typical railcar chassis, and the unit on test can be either manually controlled as by a driver or it can be controlled by an automatic cycle gear to simulate the repeated acceleration, deceleration, idling, braking, gradient climbing, and other running conditions of normal train working.

The bed, which has now been in service for some months, can be seen in the upper illustration with a railcar engine set mounted on it. The output shaft of the torque converter of the power unit is coupled through a full length railcar transmission shaft to a Mark VI Heenan "Dynamatic" dynamometer, which has a total capacity of 3000 h.p. Three heavy flywheels, driven in series with the dynamometer, are used to produce an inertia equivalent to half that of the power and trailer coach of a train set—the power coach of an actual railcar set having two such power units. A high capacity brake is used so that the energy of the flywheels can be absorbed quickly—and it is pointed out that at one stage in the automatic cycle this energy totals some 875 b.h.p.

Actual railcar control equipment is used as far as possible on the rig to allow maximum testing of the equipment on the test bed. The control system is arranged for three different methods of use—complete manual operation as by a railcar driver, automatic lock-out with manual rack control, and a fully automatic cycle of fifteen minutes' duration, reproducing the effects of a typical railcar run on the power unit. The main control desk is situated in a sound-proofed room at the side of the test bed, and from this desk the operator has a clear view of the bed through a large window.

The control system comprises air and electrical circuits, the air circuit of which is effective in all three methods of use of the equipment. Compressed air is used to select the converter drive, the direct drive and operate the rack actuator of the engine fuel injection pumps. For operating with manual control a master switch is used to select the neutral position (when the starter can be operated) the converter drive and the direct drive. When an automatic lock-out switch is moved into its lock-out position a Woodward governor comes into effect. A switch operated by this governor closes when the output shaft speed reaches 1270 r.p.m. and brings the engine control to the idling position. In this case clutch operation is delayed to ensure that the engine is synchronised before the direct drive is engaged. The engine is brought back to full rack after a few seconds' delay; after the output speed has dropped to 1100 r.p.m., converter drive is restored. An alternative method of obtaining automatic converter lock-out and lock-in is provided by a Smiths speed sensitive device.

When the automatic cycle control is engaged, a clock meter and selector equipment come into operation, and this motor drives a control cam at four revolutions per hour. The cam operates the dynamic brake of the equipment at different loads which correspond to those encountered by a railcar on level track, rising and falling gradients and when braking, with idle and neutral positions between each stage. A series of buttons on the cam which give the correct sequence of timing for a fifteen-minute cycle, selects the following running conditions:

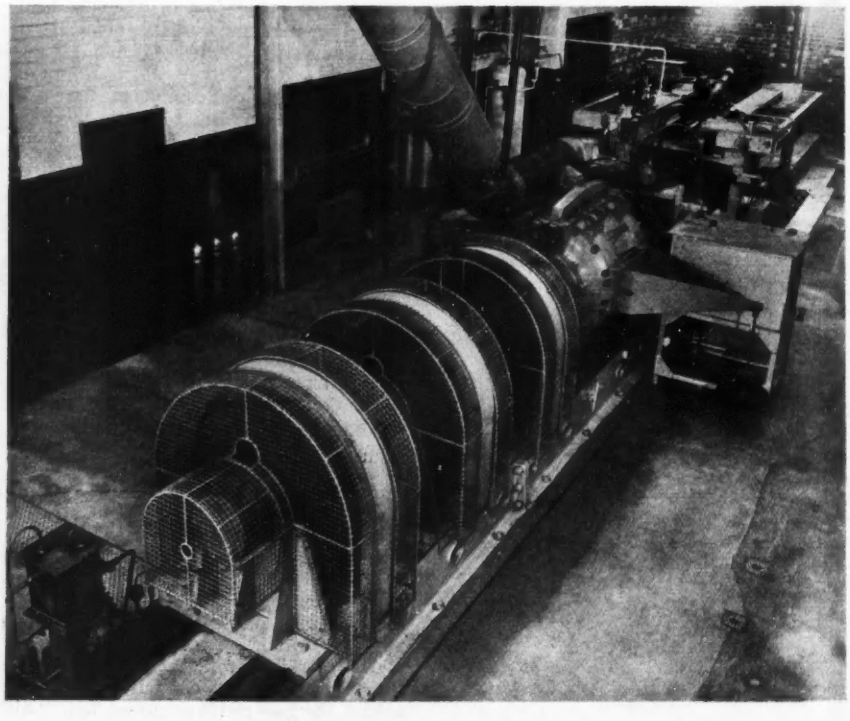
1.	5 min.	20 sec.	Up gradient
2.		20 sec.	Brake and idle
3.		40 sec.	Brake, idle and neutral
4.	2 min.	30 sec.	Level track
5.		20 sec.	Brake and idle
6.		50 sec.	Brake, idle and neutral
7.	2 min.	20 sec.	Down gradient
8.	1 min.	40 sec.	Up gradient
9.		20 sec.	Brake and idle
10.		40 sec.	Brake, idle and neutral

The buttons operate a micro-switch which actuates a three-bank, telephone type, selector mechanism. One bank is connected to a set of relays and chooses the correct "Dynamatic" brake position, at the same time lighting a pilot lamp indicating it. The other banks are connected to relays which are energised according to the time-table and to similar pilot lamps.

A micro-switch resets the selector mechanism at the end of each cycle. Position markings on the cam indicate exactly where in the cycle the system is at any time. The engine can be stopped manually at any position in the cycle and a reset device on the cam allows it to be indexed back to the initial position for starting.

The control panel in the operating room, in addition to the usual pressure and temperature gauges, carries a battery master switch; a neutral, converter and direct drive switch; a manual and automatic lock-out switch; a cam cut-out switch; a stop cam showing the cycle position; cam indicator lights; a throttle control valve, and the engine start and stop buttons.

Gauges are also mounted on a panel at the side of the engine for engine oil pressure, coolant temperature, converter fluid pressure and converter clutch pressure. This panel also incorporates stop and start buttons and an engine running light. A tachometer connection and relay cuts out the starter at approximately 250 r.p.m. and brings fault switches for low oil pressure and low coolant level into circuit. Any fault then arising will break the stop-switch circuit and stop the engine.

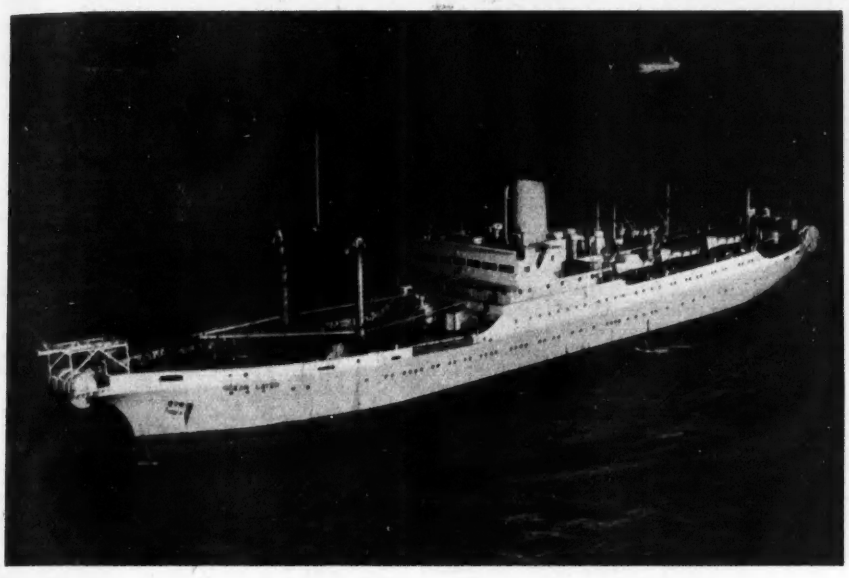


Test bed dynamometer with flywheels mounted on transmission shaft to simulate inertia of an actual railcar installation

Cable Ship "Ocean Layer"

At the end of the war Submarine Cables, Ltd., was without a cable ship, since the "Faraday II" had been destroyed by enemy action, but it was not until 1953 that the single-screw cargo ship S.S. "Empire Frome" was acquired from the Ministry of Transport, with a view to conversion to the specialised duty of cable laying. The ship was of 5360 tons deadweight and propelled by a single screw, but it was equipped with a Pleuger active rudder, which made the ship as manœuvrable for the work of cable laying as a ship with the more usual twin screw arrangement.

R. S. Hayes (Pembroke Dock), Ltd., was entrusted with the complicated and difficult task of converting the "Empire Frome" to a cable layer. Now, renamed "Ocean Layer," the ship can carry 1100 nautical miles of deep sea coaxial cable or 1875 nautical miles of average size deep sea telegraph cable. Since being commissioned the ship has been continuously on charter. Recently during loading with cable at Greenwich, before sailing to the Indian Ocean, the opportunity was taken to visit the ship.



Cable Ship "Ocean Layer"

The main particulars of the ship illustrated herewith, are: length overall, 378ft; length between perpendiculars, 322ft 1in; breadth moulded, 50ft 10in; depth moulded to upper deck, 30ft 4in; draught, 21ft 3in, and deadweight, 4619 tons. While the work of converting the hull was being carried out the original engines and boilers were overhauled and the opportunity taken to retube the three Prudham-Capus boilers and convert them to burn oil fuel instead of coal. The boilers supply steam at 200 lb per square inch and 600 deg. Fah. to the main engine, which is a Lentz No. 9 double compound, cam-operated, poppet valve unit working in conjunction with a Bauer-Wach exhaust turbine, driving the main shaft through a hydraulic coupling and a double reduction gear. The h.p. and l.p. cylinders have diameters of 420mm and 900mm, respectively, and the stroke is 900mm. To meet the high rate of engine manœuvres required in cable laying work an electrically-driven reversing gear has been fitted. At 106 r.p.m. the machinery develops 1350 s.h.p., sufficient to give the ship a speed of 10 knots. Many of the original auxiliaries have been retained and an additional evaporator of 25 tons per day capacity has been installed to satisfy increased demands for fresh water.

Mention has been made already of the active rudder, which gives increased manœuvrability to the ship, and this consists of an auxiliary propeller driven by a three phase, 400 h.p. squirrel cage motor which is mounted in the rudder in line with the main propeller shaft and housed in a pear-shaped casing. The auxiliary propeller is shrouded and the whole installation increases the overall efficiency of the main propeller. Power is developed by a 500kVA, 400V, three-phase, 50 c/s alternator, driven by an eight-cylinder, 600 h.p., single-acting, four stroke diesel engine, and transmitted to the motor of the active rudder by flexible cables which pass through the hollow rudder stock. Control of both the alternator set and the rudder is effected directly from a desk on the bridge and the steering gear provides for the use of the active rudder up to an angle of 90 deg. to port and starboard so that the ship can be moved by the auxiliary propeller without using the main engines. Other electrical requirements are supplied by two 190kVA, 400V alternators, each driven by a 200 h.p., four-cylinder, single-acting, four stroke, exhaust turbo-blown diesel engine, while for emergency purposes there is a 35kVA alternator.

There are four cable tanks, two forward and two aft, of the machinery spaces, with a total coiling capacity of 74,662 cubic feet or 3850 tons of cable, and forward is a hold for the storage of buoys, while aft is a hold for the stowage of cable equipment. On the main deck forward are two independent picking-up and paying-out gears, each driven by two Sisson three-cylinder, non-compound, vertical steam engines supplied with steam at 180 lb per square inch and each developing 120 h.p. at 260 r.p.m. When coupled through a gear train the engines give picking-up working loads ranging from 30 tons at 100ft per minute to 8½ tons at 350ft per minute. Both gears are fitted with hydraulic oil brakes which serve to control smoothly the speed when paying out cable. There are two oil brake units to port for paying out a maximum load of 8 tons at speeds up to 8 knots and one unit to starboard.

A caterpillar paying-out gear is sited on the port side of the after deck and has been designed jointly by Johnson and Phillips, Ltd., and Telcon and Post Office engineers for the paying-out of rigid repeaters. The gear is driven by the weight of the cable, paid out over the stern, which is frictionally gripped by two roller chains fitted with gripper blocks, the gripping pressure being applied by rubber bags filled with air under pressure. When handling a repeater it is put in its carriage at the forward end of the caterpillar and then eased through with the ship moving at minimum speed. A special launching cradle is used to pass the repeater over the 7ft diameter stern sheave. Although primarily designed for paying-out, the caterpillar can also pick up a short length of cable, a 50 h.p. variable speed motor being fitted for this purpose. Another 50 h.p. motor feeds the cable from the ship's tank until there is sufficient length of cable over the stern sheave to drive the winch. In addition to the stern sheave there are three sheaves at the bow, dynamometer sheaves and draw-off sheaves, all of 7ft diameter, so that the ship can handle all sizes of cable and flexible repeaters.

Modern requirements call for, in addition to the conventional testing and fault location gear, extensive carrier frequency transmission measuring equipment and sometimes power supply for the repeaters. Adequate space has been provided for this equipment in the testing room, immediately forward of which is the drum room, where there is full instrumentation to record speeds, slack, cable strains, paying-out rates and depths of water. Certain essential instruments are located at bow and stern sheaves so that laying operations can be controlled from these points. In addition to the essential radio and navigation equipment, there are items particular to a cable layer, such as local communication facilities for shore end laying operations, a range finder and oceanographic depth sounders.

While on board we were able to see a film which illustrated the great care exercised, and the considerable technique required, in the manufacture of deep sea cable, and a second film recorded the handling of repeaters while engaged in cable-laying operations. Also exhibited on board were various items of cable gear equipment. These included a rigid repeater casing and its trolley, the method of sealing the inner assembly, a flexible repeater and the results as registered by a "flight recorder," installed in a rigid repeater, of an investigation into the behaviour of a repeater during laying operations. Temperature, leak rate, time and acceleration in all three directions, together with number of revolutions, were all measured and the record showed that besides executing some peculiar movements, the repeater made about 2000 revolutions going down and a similar number coming up.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

HARD-DRAWN CADMIUM-COPPER CONDUCTORS FOR OVERHEAD POWER TRANSMISSION

No. 672 : 1957. Price 5s.—Publication of this new edition of B.S. 672 completes the work of revising the British Standards for overhead power line conductors. The series now consists of B.S. 125 : 1954, B.S. 215 : 1956, Parts 1 and 2, and the present B.S. 672 : 1957, dealing respectively with hard-drawn copper, hard-drawn aluminium, steel-cored aluminium and cadmium-copper conductors.

The main changes in B.S. 672 are a reduction in the minimum conductivity of hard-drawn cadmium-copper and the adoption of the Centigrade temperature scale. The new value of conductivity is 79·2 per cent of that adopted by the International Electrotechnical Commission for "standard annealed copper," and it corresponds with the maximum resistances specified for standard conductors since 1941, when the earlier edition of the standard was amended. The number of standard conductor sizes has been reduced and the testing procedure has been brought into line with that adopted for aluminium conductors in the recent revision of B.S. 215.

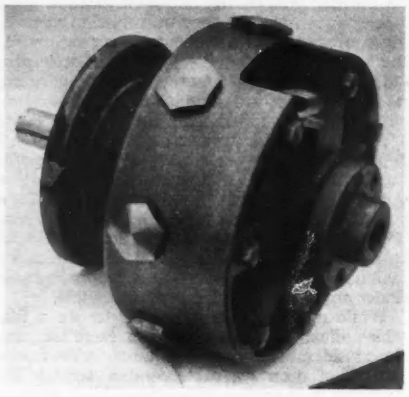
METHODS OF TESTING PLASTICS : PART 3, "MECHANICAL PROPERTIES"

No. 2782 : 1957. Price 7s. 6d. This is the latest addition to the series of standards dealing with methods of test used in the plastics industry. The publication provides details of test specimens, apparatus, procedure and calculation of results for the following methods of test :—Tensile strength and elongation at break ; elastic modulus in tension ; crushing strength ; shear strength ; impact strength ; indentation ; and tear strength.

The foreword to the publication states that many of the British Standard methods of test used in the plastics industry are being considered for world adoption by the Plastics Committee of the International Organisation for Standardisation.

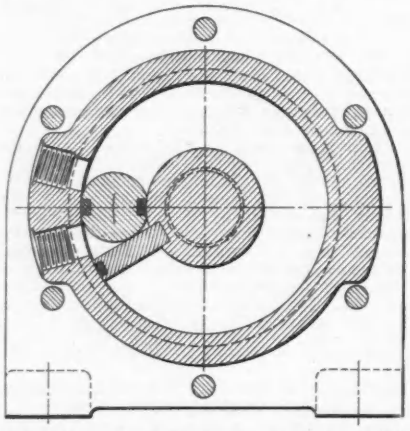
Hydraulic Control Gear

NEW items added to the range of equipment produced by the Lockheed Industrial Hydraulics Division of the Automotive Products Company, Ltd., Shaw Road, Speke, Liverpool, include a radial seven-cylinder pump that is available in three basic sizes. At a speed of 1440 r.p.m. the deliveries given are 8 gallons per minute against 1500 lb per square inch, 5 gallons per minute against 2000 lb per square inch, or 4 gallons per minute against 3000 lb per square inch, according to cylinder bore. The maker can adjust the capacity within these ranges to meet the particular requirements of users. The pump is



A seven-cylinder oil-hydraulic pump of robust design for industrial use; it is available in flange or foot mounting forms. The diameter of the body is 9·75in

stated to be especially robust. Another new item is what the manufacturer describes as a semi-rotary slave. This variety of hydraulic torque motor has lately gained some popularity in the U.S.A., and a single-vane example offered by Lockheed's is shown in our illustration. The particular claim made for the design is that sealing is relatively good. The dilatation of the cylinder does, of course, tend to increase leakage past the vane with increase in pressure. The range of angular motion is 300 deg., and torques of 1500 lb to 660,000 lb inches are said to be obtainable at a pressure of 1000 lb per square inch. With two vanes the movement is reduced to 120 deg. and the torque is doubled. A frictional lock which prevents movement when fluid pressure is released, and unlocks when pressure is applied, is a standard fitting on a



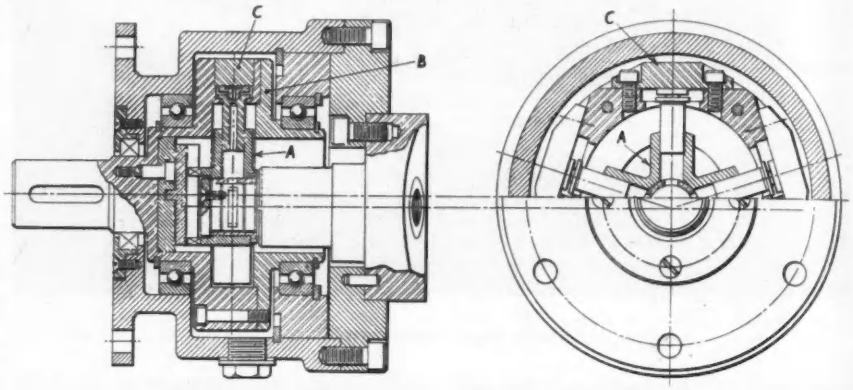
Section through single-vane torque motor, 4·25in internal diameter, 6in internal length. The model shown is claimed to provide a torque of 10,200 lb in

number of actuators produced by this company; the device (dubbed "Autoloc") can be adapted for use in the "semi-rotary slave."

The operation of boiler dampers from centralised hydraulic controllers made by Lockheeds, the company states, has been an established practice for some fifteen years. Examples quoted are the synchronised actuation of induced draught fan-damper pairs, the control of superheater by-pass dampers, and the automatic closing of fan dampers. Their success is indicated by the extension of the application of such controllers to dust-handling plants, automatic soot-blowers, and window actuators. Among the later installations are the electro-hydraulic controllers at Goldington,* Ince,† Meaford "B"‡ and Barony§ power stations. At Goldington, for instance, the equipment affords press-button control from a line diagram on which schematic model dampers indicate the positions of the actual dampers. The buttons are placed in pairs on the boiler control panel, each pair next to the indicator for the damper served. One button governs the opening and the other the closing movement.

Hydraulic Power Transmission Equipment

WE have received particulars of a prototype hydraulic pump built by N. J. Tatham and Co., Ltd., Haywards Heath, Sussex, which forms part of a hydraulic transmission equipment. This equipment will eventually be supplied either as a self-contained, infinitely variable gear, or as separate hydraulic pumps and motors in both fixed and variable delivery models. The general principle of the transmission is orthodox in that it consists of a variable displacement rotary radial piston pump feeding a hydraulic motor of similar construction in a closed circuit system. This arrangement gives a fully reversible drive, with speed adjustable from maximum through zero to maximum in the opposite direction. The pump and motor are of identical construction except that, as used in the transmission, delivery control would most often be fitted to the pump only; means of delivery control can, however, be equally well applied to the motor, this being advantageous for transmissions which have to deliver a constant horsepower at a variable speed.



Fixed capacity hydraulic pump or motor for hydraulic transmission equipment

In a typical motorised transmission the pump and motor would be arranged back to back and rotate on a double-ended pintle which provides a short, straight path for the oil. Relief valves would be built in to prevent overloading, and a small gear pump included to replenish leakage losses in the system from an oil sump in the base of the transmission casing.

The arrangement of a fixed capacity motor or pump can be seen in the drawing we reproduce. It is of five-piston, radial construction, and in it particular care has been taken to ensure that the interface pressure between the pintle and rotor accurately balances the piston load.

The cylinder block *A* rotates in synchronism with a track *B* supported on ball bearings. This track carries flat bridge pieces *C* on which the pistons bear through an articulated pad mounted on a spherical seat. A small bore connects the pad surface with the pumping chamber at the bottom of the piston and the top of this bore is surrounded by a very shallow recess, the effect of which is to create hydrostatic lubricating action which reduces wear on the working surfaces to a minimum.

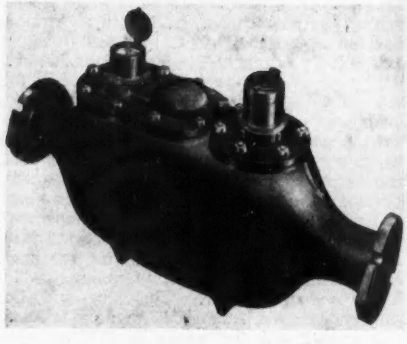
The drive is taken directly to the track, which takes the torque, and the cylinder block is driven from the track by a small Oldham joint, which only has to transmit quite small torques due to friction and minute misalignments.

The variable delivery pump differs from the fixed delivery unit in that the track bearings, instead of being fixed, are carried in rings bolted to a pair of sliders working in a cross bore in the pump casing. Through these sliding members the eccentricity of the track can be varied in respect to the pintle by a handwheel, servo or other form of control.

We are informed by the makers that pumps which have been designed for a maximum continuous working pressure of 3000 lb per square inch can be overloaded to 4000 lb per square inch at intermittent rating. Based upon results with the prototype pump, there is claimed a volumetric efficiency of 98·6 per cent and an overall transmission efficiency of the order of 90 per cent is expected for a pump/motor unit.

Industrial Water Meters

A NEW class of trade water meters, known as the "Compound," has been introduced by George Kent, Ltd., Luton, for the measurement of widely varying cold water flows. The meter is stated to have an extremely wide measuring range, which, in the case of the 3in model, is over 500 : 1 within accuracy limits of 2 per cent. To achieve this range two completely separate measuring units are used, one for high and the other for low flows, both of which, with an automatic change-over valve to select the unit required, are contained in a single compact meter body, as shown in the accompanying illustration.



New compound water meter, incorporating separate measuring units for high and low flows

Only one measuring unit in the meter can register at a time.

Basically, the "Compound" meter consists of a body casting containing four main components: a high and a low-flow measuring unit, an automatic change-over or pilot valve, and a main valve. At low flow rates both the pilot and

* THE ENGINEER, August 16, 1957, page 230.
† THE ENGINEER, October 18, 1957, page 566.
‡ THE ENGINEER, October 11, 1957, page 533.
§ THE ENGINEER, October 25, 1957, page 607.

main valves are in their bottom positions, and the flow is passed through the top skirt of the pilot valve to be metered by the low-flow measuring unit, which is a standard "Master" semi-positive rotary-piston water meter. As the flow approaches the change-over point, it exerts sufficient force to overcome the weight of the pilot valve, which starts to rise. This action is assisted by the impact of the flow stream on a small disc attached to the top of the pilot valve. As the pilot valve begins to rise, the flow through its top skirt is restricted, thus increasing the upward forces acting on it so as to give an abrupt valve movement. The pilot valve in this new position completely cuts off the flow through the "Master" meter. As the pilot valve rises a passage is opened through its bottom skirt and the flow is diverted through a cored channel in the meter body, to be measured by the high-flow unit, which is a standard "Torrent" inferential water meter. Up to this point, the main valve remains closed, but the pressure drop across the bottom section of the pilot valve also acts across the area of the main valve, tending to cause it to lift. This rise is assisted by the pressure drop across the "Torrent" meter, which acts upon a piston lifting the main valve to the position of minimum loss of pressure. With a decrease in the flow rate to the change-over point, the "Compound" meter operates in the reverse manner, the main valve dropping first, followed by the pilot valve. Again, the pilot valve movement is sharp. The valves are designed so that the flow is returned from the high- to the low-flow unit at a flow rate approximately 100 gallons per hour below that at which the change-over from low to high takes place, thereby eliminating any possibility of valve "hunt." To read the meter, all that is necessary is to add the quantities shown on the two straight-reading counter dials, the standard meters being calibrated in Imperial gallons, cubic feet or metric units.

Portable Resistance Welders

A RANGE of robust portable resistance welders is announced by Portable Welders, Ltd., 225, Westminster Bridge Road, London, S.E.1. Basically, there are three models, differing according to the duties they have to perform. The lightest is known as the "Leopard Autospot," and is said to be designed for such work as the

A portable welding machine intended for such work as the repair of motor-car bodies is here shown in use

repair of motor bodies, the fabrication of sheet metal, and tack welding for sub-assembly processes. Using mains supply at 220V to 230V, 50 c/s, single-phase, with a welding rate of 4·8kVA and a secondary welding current of 5000A at the electrode tips, these spot welders are available with four different arm arrangements, giving throat depths up to 13in. The tip pressure with 6in arms is 550 lb, according to the maker's specification, and the weight overall (but without arms) 25 lb.

Described as a "heavy-duty" model, the "Leopard S.70 C" spot welder is said to be representative of the machines produced by this company for production work. With a power factor not far from unity, the mains current drawn is stated to be well below 50A, and this is compared with the 300A to 400A required by the standard hanging-cable welder. A toggle mechanism on the hand-operated model is reported to give a tip pressure of 600 lb with an 8in throat depth. The rating is quoted as 8·5kVA and the electronic timer is stated to give welding periods of a twenty-fifth to one and a half seconds. A sling can be fitted to permit a turning circle of 180 deg. For heavier work still, the "Leopard S.100" machine is offered. Fundamentally similar to the "S.70," this is specified to have a welding rate of 10kVA, and to be capable of higher production speeds.

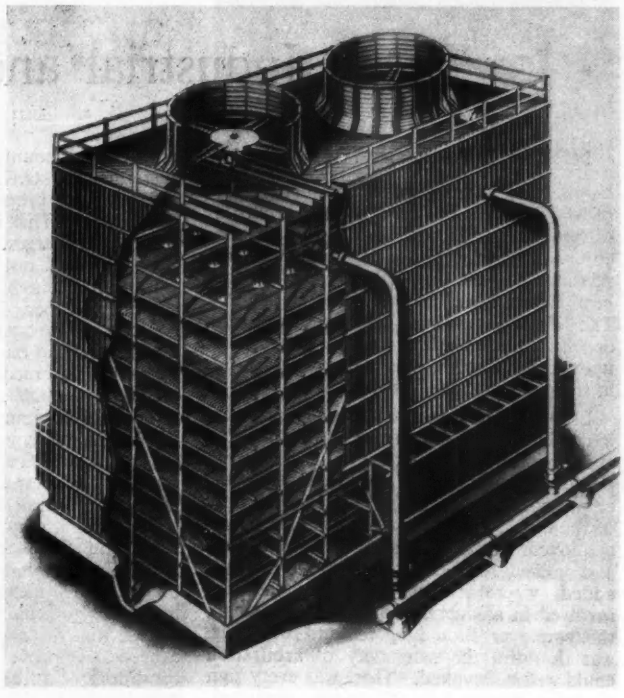
The company informs us that it has moved into a new factory recently completed on the Bletchley industrial estate, and that these "Leopard" machines are at present in production. A portable arc welder is stated to be in prospect for the near future, and developments in spark erosion machining for the aircraft industry are also planned.

Mobile Crane Demonstration

AN interesting series of demonstrations was given recently at the Sunderland works of Steels Engineering Products, Ltd., to show the applications for which "Coles" Mobile Cranes are suited in the iron and steel industries. In these demonstrations various types and sizes of the firm's well-known diesel-electric self-propelled, truck-mounted and rail cranes showed their capacity for handling plates, bars, billets, pig iron, scrap and swarf as well as for erection work. Typical rail and road vehicles were loaded and unloaded and stockyard handling exercises were carried out using the cranes fitted with hooks, clamps, magnets, grabs, &c.

A particular point stressed in all the demonstrations was the manœuvrability and speed of the cranes and the degree of precision with which loads could be positioned. In one such exercise a length of pipe was inserted into another length standing upright on the ground, there being only $\frac{1}{8}$in clearance between the bore of the standing pipe and the outside diameter of the inserted pipe. A length of pipeline was raised, positioned and coupled up in a matter of minutes in a second demonstration. Probably the most impressive piece of work carried out was the raising and positioning on its gantry of an overhead crane bridge in one of the firm's new shops. This bridge, weighing several tons, was handled by an "S.2710" mobile crane fitted with a 60ft jib. The complete operation was carried out in about four minutes by a driver and four erectors. Within eight to ten minutes the jib had been manœuvred down from a small hole left in the roof glazing for erection purposes and the crane prepared for driving out of the shop.

The use of stockyard rail cranes for shunting was shown by moving wagons between the demonstration points and finally by a crane pushing three empty wagons up a 1 in 25 incline.



Artist's drawing of a new design of induced-draught cooling tower. The maker reports that the low height and unobtrusive appearance, compared with conventional hyperbolic natural-draught towers, are attractive from the architect's point of view

Induced-Draught Cooling Tower

IT is announced by Head Wrightson Processes, Ltd., that work has been completed on a new design of the "Counterflo" induced-draught cooling tower. This type of tower is used in the United States, and the company offers it in the United Kingdom and British Commonwealth under licence from the Fluor Products Company of Los Angeles. Continuous research on methods of cooling is stated to have produced some novel features. The tower can consist of one or more cells each with an induction fan which draws the air through the tower from louvre intakes. Water passes down the tower from an all-timber totally enclosed distribution system through splash grids. The tower is built of prefabricated timber or concrete units. Asbestos panels sheath the towers in certain circumstances. Erection of all types is claimed to be rapid and simple, with flexibility in operation due to individual cell control.

"Counterflo" cooling towers are said to be in use at oil refineries, chemical plants and on many industrial sites throughout this country, and in the rest of the world. Recently, we are informed by the manufacturer, a concrete version was supplied to a Government department to cool 4,000,000 gallons of water an hour; this is thought to be the largest installation of its kind in the United Kingdom.

I.E.E. AWARDS.—The Council of the Institution of Electrical Engineers has elected Mr. H. T. Young, a past-president of the Institution, to Honorary Membership, in recognition of fifty years of devoted service in promoting the wider use of electricity in the service of man and, particularly, its full and safe employment in buildings of every kind. In making this award, the Council pays tribute to Mr. Young's work over many years in the development of the I.E.E. local centres, in the formation of the Utilisation Section, of which he was the founder chairman, and in giving help and encouragement to the Students' Sections. The Council has also made the thirty-sixth award of the Faraday Medal to Sir Gordon Radley, K.C.B., C.B.E., Ph.D. (Eng.), the immediate past-president of the Institution, for his outstanding contributions in the field of international communications and particularly in the development of long-distance, deep-sea telephone cables and their repeaters.

Industrial and Labour Notes

Industrial Relations and Wages

In an address at the annual conference of the Institute of Directors, on Thursday of last week, Viscount Chandos made some comments on the present state of industrial relations and on wage claims which, it had been stated, would be pressed by the unions. The life and vigour of the nation, he said, depended upon reaching a working agreement upon the subject of wages and wage claims in the present phase of the economy.

Lord Chandos went on to say that where it was clear that an increase of wages would endanger or perhaps undermine the competitive power, and, consequently, the employment in an industry, it was the duty of the employer to resist wage claims by the employed, and "he should not be abused and vilified for doing his duty." But, he added, where it was clear that the risk involved in an increase of wages was small, the employer should agree, and where he was doubtful the machinery of arbitration could well be invoked. There was every sign at the moment, Lord Chandos continued, of a clash between trades unions and employers, with the Government becoming involved; wage claims would have to be examined with patience, though at present it did not appear that there was a *prima facie* case for agreeing to them.

Lord Chandos then went on to express his personal conviction that the whole attitude to wage claims must be realigned. Provided, he said, that agreement was over a wide enough field—a field which must clearly embrace the majority if not all of the nationalised industries—he believed in a wage agreement incorporating certain defined principles. First of all, Lord Chandos suggested, there should be longer notice of termination of employment, based upon the length of service of the man employed; and, secondly, there could be a wage agreement covering five years and giving an annual increase in the basic wage of, say, 2½ per cent per annum to every employee who had served his "reference period" of a year or two. That 2½ per cent, Lord Chandos explained, would be calculated not upon earnings, but upon the basic wage rate, and would be part of an agreement that no wage claims would be advanced during the five years. There would have to be, he added, some qualification that the increase would not be automatic if there were special conditions which assailed a particular industry. It would, however, be the duty of the industry to prove the case against an advance and not the task of the unions to prove that an advance was justified.

Association of Engineering Distributors

Dr. D. B. Foster, a director of the Mullard Equipment Company, Ltd., addressed the Association of Engineering Distributors at its annual general meeting in London on November 5. Taking "The European Free Market and the Engineering Industries" as his subject, Dr. Foster said that the European common market between the six countries could be regarded as an established fact. Present British trade with the six was about £500 million a year, and, unless we entered into some arrangement with them, we could expect to see this trade progressively extinguished. It was unthinkable that this country should stand aside, and therefore the U.K. had collaborated with O.E.E.C. in proposing a European Free Trade Area. This industrial economic unit would be the largest in the world. The reason why we could not simply join in with the European Economic Community to make a seventh member, Dr. Foster said, was, of course, that we could not join in establishing a common tariff barrier against the Commonwealth. The reconciliation of the British idea with the *fait accompli* of the European Economic Community would no doubt be realised in due course, and British engineering industries were concerned with the effect on their livelihood. It was clear that the main competition would come from highly industrialised countries with lower labour rates, countries such as Germany, Holland and Italy. Labour cost, however, was only one of many factors; material costs were of equal significance. On balance, we could deduce that the engineering industries might expect to improve their position under the conditions of a free market. The three great new factors in the second industrial revolution, continued Dr. Foster, were atomic energy, electronics and new materials. Provided that we could keep up our present rate of development in these new lines, and provided that we could take the correct marketing measures, the labour rates in countries such as Germany should not worry us too much.

Broadly speaking, the battle could be won in the laboratory and the drawing-office rather than on the production floor. Taken as a whole, Dr. Foster concluded, British industry should not be adversely affected by the European Free Market.

Research and Management

Last week, the British Institute of Management held its annual conference at Bournemouth. The theme of the discussions at the conference, and of the many papers presented at the sessional meetings was "Research—a Signpost to Better Management."

One of the papers, by Professor G. F. Carter, of the Queen's University, Belfast, was entitled "Research: A Management Technique." It indicated several ways of ensuring effective research in industry. The choice between research projects, Professor Carter urged, required economic and managerial thinking of a high order. For a new product, one had to make guesses about the size and rate of growth of the market, about the reaction of competitors and the likely production costs, and about the reaction of the product (if it was made) on the structure of the company. There was no sense, Professor Carter observed, in starting something which would obviously be too big to be handled, too expensive to be financed, or too explosive in its reactions on the managerial structure of the company.

Professor Carter went on to say that the important thing to remember was that, if there were people with lively minds about, there would be far more projects put up for consideration than could possibly be used. A choice had to be made on some grounds; it was best that the grounds should be rational. Usually, other projects must be weeded out when they were half-grown; there must be machinery by which a change in circumstances was able quickly to exert its influence on the research plans. A further, and drastic, weeding out was needed, Professor Carter added, at the stage where research passed over into development or design, i.e. where small-scale laboratory work gave place to the design of prototypes and pilot plants. That was partly because, at the end of the research stage, a new assessment of technical possibilities (and therefore of production costs) could be made; and partly because in many firms development was a far more expensive process than research. The main point, Professor Carter urged, was that research and development should be "cost and profit minded," and closely related to what was going on elsewhere in the company.

International Scrap Federation

The autumn congress of the Bureau International de la Recuperation was held in London last week. The B.I.R., which was founded in 1948, is an international federation of many national federations concerned with ferrous and non-ferrous scrap, textile waste, waste paper and other various forms of waste material, and now includes fourteen active member countries. A statement issued at the end of the conference said that the meeting in London had assumed a particular importance in view of current developments in European free trade. There had been some very lively discussions, the statement continued, particularly on the iron and steel scrap side, as there were some most difficult problems to be solved before a real European Free Trade Area could be achieved. The iron and steel scrap problem was particularly difficult because of the influences it could have upon United Kingdom steel prices and on the products made from steel.

The European membership of the B.I.R. is responsible for over £150 million of international business each year, the statement pointed out, this figure referring purely to the interchange of materials between countries, whilst in the United Kingdom the iron and steel scrap industry alone supplied appreciably more than £50,000,000 worth of material to the British iron and steel industry in a year.

Employment and Unemployment

The Ministry of Labour has reported "little change" during September in the numbers in civil employment in Great Britain. At the end of the month the total in civil employment was 23,109,000 (15,292,000 men and 7,817,000 women). Of the total, 9,217,000 were at work in the manufacturing industries, which was 31,000 more than a month earlier. The principal increase (13,000) was in the engineering, metal goods and precision instruments group, the labour force of which at the end of September totalled 2,806,000, compared with 2,808,000 a year earlier.

About unemployment, the Ministry says that on October 14 there were 275,222 (about 1·3 per cent of the total number of employees) registered as out of work, compared with 267,406 on September 16. Of the October total, 267,030 were wholly unemployed and 8192 were temporarily stopped.

Reinforced Concrete Headgears in South Africa

BY OUR SOUTH AFRICAN CORRESPONDENT

A COMPARATIVELY new development in the construction of mine headgears in Southern Africa relates to the use of reinforced concrete structures in place of the erstwhile braced steel structures so familiar for many years on the landscape of the Rand. In this development, the Roberts Construction Company, Ltd., has been responsible to date for eleven of the newer reinforced concrete units. Three of these have been constructed in Rhodesia, some on the East Rand, whilst the others are situated mainly in the Klerksdorp area, with one, the latest, in the Orange Free State field. It is the main purpose of this article to describe in some detail the last-mentioned of these structures, but some reference, first of all, to some of the others may be of interest.

The Hartebeestfontein Gold Mining Company, Ltd.—The new reinforced concrete mine headgear for No. 2 shaft on this mine is shown in the background of Fig. 1, and was built as a structural continuation of the shaft collar. This headgear, which is 150ft high, will be seen from the illustration to resemble a lighthouse in shape.

Fig. 1—A new headgear for the Hartebeestfontein No. 2 shaft can be seen in the background, looking rather like a lighthouse

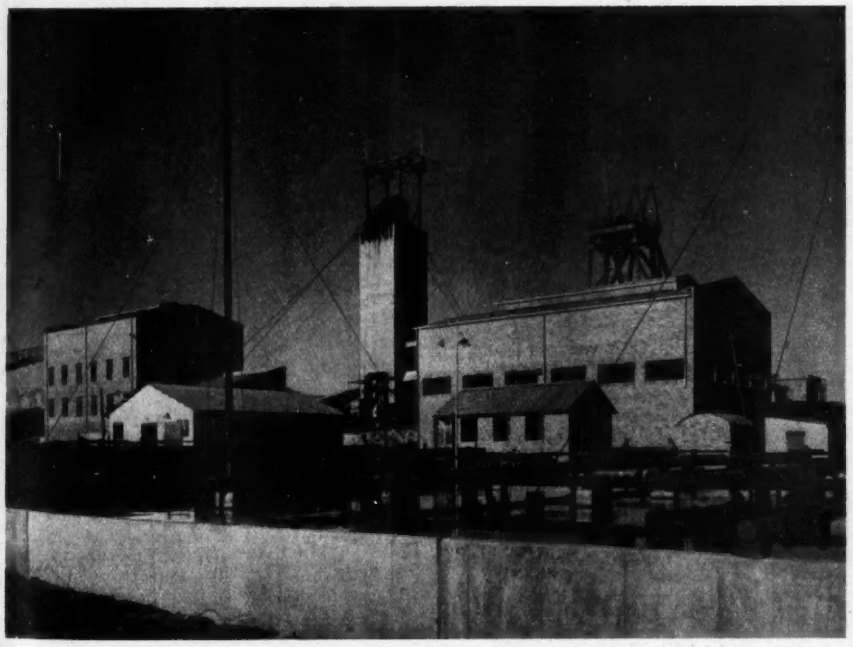


Fig. 2—The headgear at West Driefontein Gold Mining Company, Ltd., No. 5 shaft contains one ground-mounted drum winder and two tower-mounted Koepe winders

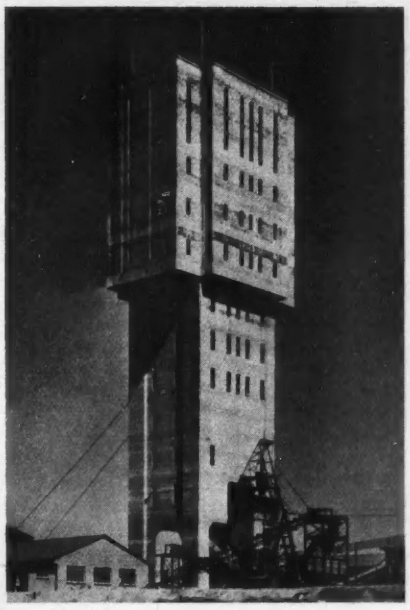


Fig. 3—In the headgear at Vaal Reefs Gold Mining Company, Ltd., prestressing of the vertical members was introduced

West Driefontein Gold Mining Company, Ltd.—The headgear on the No. 5 shaft of this mine (Fig. 2) is an interesting structure of rectangular form and, as can be seen, of somewhat unusual outline. This structure accommodates one ground-mounted drum winder, with two Koepe winders housed in the tower and, as shown in the illustration, these requirements have resulted in a structure of striking form and by no means unpleasing appearance.

Vaal Reef Gold Mining Company and Wit. Nigel Gold Mining Company.—The headgears for both these mines are here considered together and shown in Figs. 3 and 4, because they are examples of rectangular structures in which prestressing of the vertical members was introduced, resulting in appreciable economy in steel requirements.

New Concrete Headgear For The Riebeeck Mine, Near Welkom, O.F.S.

This, the most interesting and recent example of reinforced concrete headgear construction is now practically completed. It was designed for the Riebeeck Mine, the latest gold mine in the Free State, in the drawing-office of Roberts Construction Company Ltd., in close consultation with the chief mechanical and electrical engineer of the Anglo-Transvaal Consolidated Investment Company, Ltd., and Professors Jennings and Ockleston, of the University of the Witwatersrand.

The structure is virtually an extension of the circular shaft and rises 150ft above ground level. Some idea of its general outline can be obtained from the illustration, Fig. 5, showing a model of the structure. The dark coloured lower portion of this model must be pictured as being below ground.

The shaft collar, which has a diameter of 30ft with 3ft thick concrete walls, was sunk like a caisson. A ring of 5ft height was cast at ground level and then, by judicial excavation, sunk into the ground, followed by a further lift of 5ft and further sinking. When the correct depth was achieved, the cutting edge at the bottom of the shaft collar was cut away and a toe cast *in situ*. The dimensions of the toe are 8ft by 10ft and at this stage the diameter was reduced to the shaft diameter of 26ft. The top 15ft of the shaft lining was increased to 2ft 6in thickness and reinforced. The shaft itself will, in the initial period of its operation, accommodate two 8-ton Kimberley skips and two double-deck man cages to carry seventy-six men in each. Provision is also made for a further two bottom discharge skips of 15 tons capacity each.

The headgear structure itself, which is 35ft in diameter with 18in thick walls, was slid by the

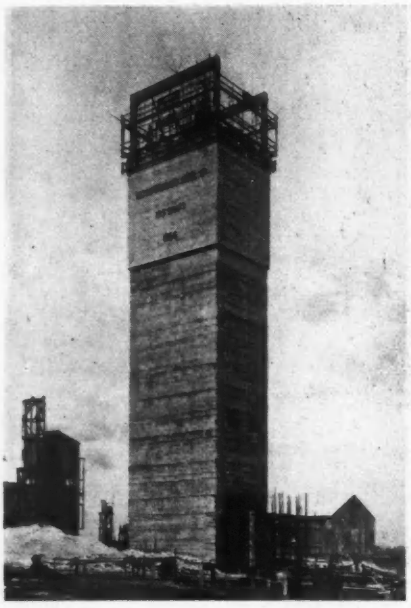


Fig. 4—In the headgear for Wit Nigel prestressing of the vertical members was also introduced

Prometo system of moving form work. This system, which uses hydraulically controlled climbing jacks on rods encased in the concrete, is a continuous process, and it was estimated that the full height of the shaft, which is just over 150ft, would be completed in about fourteen days. Actually, the job was completed sixteen hours ahead of schedule.

Provisions for various openings in the headgear were made as the sliding proceeded, as well as pockets to support the sheave platform and ore bins which were added after the main body of the headgear had been completed on either side of the structure. Winders are situated on three sides of the headgear and all sheaves are located at one level, which is 124ft above bank. A flat 24in thick concrete roof slab covers the structure and extends over the sides to a diameter of 59ft.

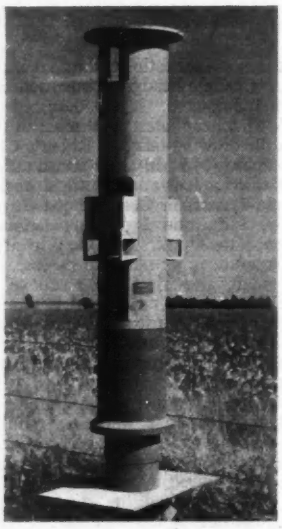


Fig. 5—In this model of the headgear for the Riebeck mine the dark-coloured lower portion must be taken to be below ground level

The headgear has been designed to accommodate a Koepe winder on top of the roof slab, if this should be required at some future stage.

The headgear and shaft collar are being constructed by the Orange Free State branch of the Roberts Construction Company, Ltd., which is the sole licensee of the Prometo system of moving form work.

Ships Diverted From Suez Canal

AFTER experience with diverted shipping, following the closing of the Suez Canal, it is possible to assess the massive contribution, made by the Union's ports, to world trade. The first of the ships diverted from the Suez Canal reached Cape Town on August 6, 1956, and Durban on August 8. During the six months up to the end of last January, the four harbours handled 1217 diverted ships, 712 to Cape Town, 477 to Durban, twenty-five to Port Elizabeth and three to East London. It was easy to meet all water requirements in full. In spite of the fact that the heavy influx of additional shipping had to be handled with the available port facilities, this was done with only minor delays to shipping.

The South African Railways and Harbours authorities, in the early stages, with no positive information to guide them, set up a shadow organisation to co-ordinate services to shipping should such a step be necessary. It was found unnecessary to establish the organisation as contemplated, since established port services proved equal to the task, with some minor additions. Some special measures were taken at both Durban and Cape Town and these proved effective. Two tugs were placed on twenty-four shifts at both Durban and Cape Town. Additional berthing gangs were appointed and a number of tug and dredger masters who were qualified to undertake pilot duties, were deputed to act as pilots. In addition, port working was started at Durban at 5 a.m. instead of 6 a.m. Some difficulty was experienced in providing oil bunkers to the large volume of shipping which commenced arriving at Durban on November 10 last year. The oil companies planned, however, to rearrange their pipelines in the Island View berths, thereby considerably increasing the number of points in that area at which bunkers could be supplied.

Enlargement of East London Harbour

IMPROVEMENTS to East London harbour have now been under way since August last year, as referred to recently in the *South African Railway News*. They include the building of a new tanker berth, at a cost of £355,650, and the widening of the turning basin, at a cost of £580,000. It has, however, been decided to plan on an even larger scale in order to provide for the new Union-Castle liners now under construction for the England-Union mailboat service and for to-day's modern oil tankers. An amount of £2,305,000 was sanctioned by Parliament this year for this purpose.

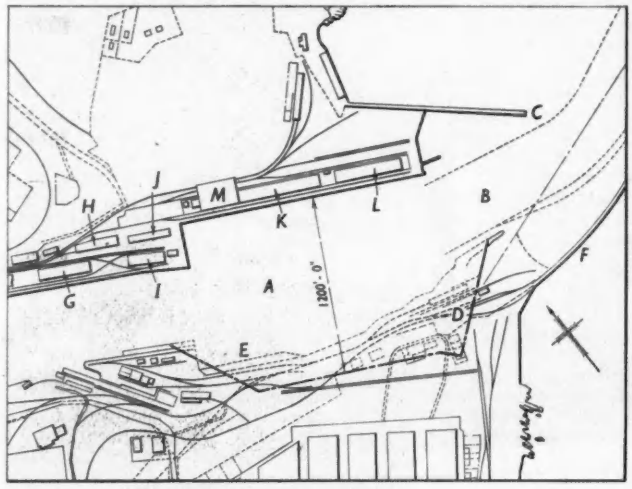
The revised project provides for a turning basin, 1200ft wide, 1800ft long and 35ft deep, and a tanker berth 850ft long, which will take one oil tanker at a time, whereas the original plan provided only for the construction of a re-entrant oil tanker berth and widening of the turning basin to 1070ft. Referring to the diagram the area indicated by bold dotted lines will now be excavated.

The work on the turning basin is being done in two stages. Stage one is the widening of the basin to approximately 1070ft and the completion of this is scheduled for the end of 1958, to coincide with the placing in service of the "Pendennis Castle," which will have a length of 764ft. Stage two will be the widening of the basin to the full width of 1200ft and should be completed by the end of 1960 when the new Union-Castle mailship "Windsor Castle," with an overall length of 783ft, starts its run between England and South Africa.

The existing turning area in the C.W. Malan Basin is 970ft wide and 1800ft long with a depth of 35ft L.W.O.S.T., and the oil tanker berth consists of a wooden wharf 454ft long.

Nearly 1,300,000 cubic yards of rock and soil will require to be excavated. A dredger will be used to clear most of the underwater spoil, which will be dumped at sea, but this part of the work will have to be speeded up. In order to assist the dredging plant it has been decided to use three second-hand bridge spans as cantilevers based on the shore. These will project over the water to hold platforms from which underwater rock drilling can be undertaken. Grabs and draglines attached to the cantilevers will pick up the broken rock within their reach. This spoil, together with the dry material removed above water level, will be taken by lorries and dumped on the foreshore to the south of the breakwater.

The channel at the entrance of the harbour will be widened by removing the underwater rubble mound from the end of the east pier, which will be faced with a vertically faced roundhead.



A.—Turning basin.
B.—Harbour entrance channel.
C.—East pier.
D.—New oil tanker berth.
E.—Existing oil tanker berth.
F.—South break-water.
G.—
H.—
I.—
J.—
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L.—
} Harbour sheds.
M.—Pre-cooling store.

Plan showing the extent to which the C. W. Malan turning basin at East London harbour will be enlarged

Industrialisation of Northern Natal

NORTHERN Natal, comprising the towns of Estcourt, Ladysmith, Newcastle, Vryheid and Dundee, is expanding and forging ahead industrially at a rate faster than ever before. Plans for a new native township at Estcourt, which will cost nearly £500,000, have been approved by the Government, 1400 acres of ground having been already acquired in this connection. Vryheid, the fourth largest town in Natal, seems to be embarking on an industrial boom period. Supplies of coal, anthracite, coke, lead, manganese, zinc and fluorspar are all to be found within 3 miles of the town. In 1955, a total of 250,000 tons of coal were produced in the Vryheid area and, in 1956, a new mine, 20 miles from the town, began production. The reserves in this particular area alone are estimated at 15,000,000 tons. About 100,000 tons of coke are being produced each month, most of which is sent to the Iscor steel works.

In the past two years Ladysmith has become one of the premier industrial towns in Northern Natal. One 110 acre industrial site is already fully occupied and another, covering 300 acres, has been laid out. At Newcastle, there is a major scheme to create a native township on its eastern boundaries, a scheme which will undoubtedly contribute much to the town's industrial future. Dundee is fast becoming the capital of Northern Natal and will soon be able to boast a large block of new Government buildings to house the Departments of Agriculture and Lands.

Verein Deutscher Eisenhüttenleute

ANNUAL MEETING

This year's meeting of the Verein Deutscher Eisenhüttenleute (VDEH)—the German Iron and Steel Association—took place in Düsseldorf on October 24 and 25. About 4500 members, including 200 from abroad, had notified their participation. On October 24 five sectional meetings were held, some of them simultaneously, in which papers were given dealing with steel plants, hot and cold forming, transport and material handling, blast-furnaces, and the technology of materials. These meetings were followed on October 25 by the Association's annual general meeting and the principal session.

THIS year's meeting of the VDEH—Verein Deutscher Eisenhüttenleute—took place against a background of continuing full employment in the German iron and steel industry. In the period January to September crude steel production in the Federal Republic increased by 5·2 per cent over the same period of last year; this rate is equivalent to about 24,500,000 tons per annum. Germany now ranks third as a steel producer behind the United States of America and the Soviet Union, while producing about 40 per cent of the output of the European Coal and Steel Community, in which it occupies the first place.

The first day of the meeting, October 24, was devoted to a number of sectional conferences, at which papers dealing with a variety of technical aspects were read.

Section 1 : Steel Works

Professor B. Kalling and F. Johansson (Domnarvet) spoke to the theme "Refining in Rotary Furnaces According to the Kaldo Process." By contrast with the LD process, the Kaldo process uses an inclined, quickly rotating rotary furnace and high-percentage oxygen. The increased stirring of the melt is stated to give a favourable reaction, particularly with phosphorus-rich crude iron. Removal of phosphorus takes place readily before that of carbon. The carbon monoxide formed is oxydised within the furnace to carbon dioxide, giving a favourable heat economy. Sulphur is reduced to one-quarter of the original sulphur content, nitrogen in the steel ranges from 0·002 to 0·003 per cent. Dr.-Ing. A. Richter, Dipl.-Ing. G. Cohnen, and Dipl.-Ing. P. Jacobi (Witten) spoke about "the basic hot-blast cupola, the Siemens-Martin steel plant and the oxygen crucible as a combined production unit." Such a plant had been in successful operation at Gusstahlwerk, Witten, for over one year. The hot-blast cupola could use a larger proportion of ore or Renn iron in place of scrap, and the Siemens-Martin furnaces, which operate with 40 per cent liquid cupola iron, had shown an increase in output of 30 per cent, together with a decrease in the heat consumption of over 20 per cent per ton. Some of the cupola iron was used in an oxygen crucible plant.

Dr. H. Trenkler and Dr. R. Rinesch (Linz-Donau) spoke about "The Suitability of the LD Process for High-Phosphorus Crude Iron." While the LD oxygen process had in recent years begun to replace the Siemens-Martin open-hearth process for iron of average phosphorus content, it was only very recently that a promising approach had been found to applying it to phosphorus-rich Thomas iron. For iron with intermediate phosphorus contents it had been shown that up to 0·5 per cent P. the LD process could be applied in one stage, up to 1·3 per cent P. in two stages. One advantage of the LD process was its high output rate (time per melt in 30-ton crucible, up to thirty-five minutes), with the consequent small wear of the refractory lining.

In his paper "The Basic Hot-Blast Cupola Furnace in a Mixed Steel Plant," Dr.-Ing. H. Voigt (Salzgitter-Drütte) described the Salzgitter plant, where output was increased from 85,000 to 125,000 tons per month by installing two additional blast-furnaces and a hot-blast cupola plant. Compared with a 100 per cent solid input, the capacity of the Siemens-Martin furnaces was more than doubled by using 40 per cent duplex Thomas iron, 40 per cent cupola iron, and 20 per cent scrap. Two cupola furnaces, each of 28 tons per hour output capacity, could be used simultaneously, using 20 per cent coke, and giving a product containing 2·3 to 3·2 per cent carbon. A novel cooling system yielded 2·5 tons of steam at 42 atmospheres per furnace per hour.

Section 2 : Hot and Cold Forming

Dealing with the subject "Planning and Operation of a Modern Fully Continuous Medium Strip Mill," Dipl.-Ing. H. Severing (Hohenlimburg) described the installation by Hoesch-Walzwerke A.G., Hohenlimburg, of such a mill, which came into service in 1955. The width of strip ranged from 150mm to 550mm, and a coil weight of 7 kg per millimetre of width was reached. Special consideration was given to the control of temperature not only in the furnaces but also during rolling.

"The Influence of Rolling Conditions on the Structure of Mill Scale and the Pickling Properties of Hot-Rolled Strip" was the subject of a lecture given by Dr.-Ing. W. Lueg (Düsseldorf) and Dr. ver. nat. W. Dahl (Berlin-Charlottenburg). For the study of pickling of hot-rolled strip an experimental arrangement had been devised, which permitted the continuous measurement of losses in weight, electric potential and current distribution during the pickling of small test sections. Preliminary tests had shown that marked weight losses began only when the potential of the sample against a standard electrode had fallen to negative values. Mill scale on commercial grade hot-rolled strip consisted of more or less irregular and porous layers of oxides. The scale thickness increased with temperature and with the time of exposure to air. Pickling speed decreased with coil weight, since slower cooling promoted decomposition below 570 deg. Cent. of Wustite (ferrous oxide) into the less soluble magnetite.

Dipl.-Ing. A. Duphorn (Hamm) said, on the theme "The Question of Mechanical Descaling of Wire by Blasting," that experiments had been carried out with rolled wire of Thomas steel, soft Siemens-Martin steel, and also steel with 0·77 per cent carbon. These wires were further processed in the usual manner and their behaviour was compared with that of wire descaled by bending and by pickling. The blast-descaled wire was cleaner and less rough than wire descaled by bending, but was worse in these respects than pickled wire. Die-drawing properties were in the same order. The cost of blasting was 20 per cent above that of pickling.

Section 3 : Transport and Materials Handling

"Planning Data for the Organisation of Bulk Materials Handling in Steel Works" was the title of the paper presented by Dipl.-Ing. V. v. Branconi (Duisburg). The high demands upon transport facilities could only be fulfilled if the given problem was correctly understood, installations were not over-dimensioned, and individual sections were brought into proper harmony with one another. Valuable design information could be obtained by plotting separately against horizontal and vertical distances, the ratio of useful to dead load, as well as obtaining the relationship between the product "useful load × useful distance" and the product "dead load × useful load × total distance." Studies of the unloading of sixty-one ships in six steel plants had shown that the actual capacities ranged between 10 and 45 per cent of the theoretical value, but lay mostly between 20 and 25 per cent. It therefore was better to improve the utilisation rather than increase the design capacity.

Dipl.-Ing. K. Rosenbaum (Essen) said, in his lecture, "Principles for the Evaluation of Ore Handling Installations and Storage Dumps in Ore-Loading Ports, Maritime Ports, and Works Harbours," that influence and order of magnitude of the various factors had to be viewed from the question of economic operation and low capital cost. He illustrated, by means of examples, the effect of throughput, loading and unloading peaks, number of grades handled, and the dimensions of the site, upon the selection of the technical equipment and the manner of installation. Ore transporters of over 50,000 tons carrying capacity would play a special part. The development of definite sizes of ship for each purpose was only just beginning. Since large handling installations were inadequately exploited if the size of ships varied greatly, it would in many cases be more economical to install smaller handling facilities now and replace them by larger ones in perhaps ten years' time, when optimum ships' sizes would have been more generally adopted.

Dipl.-Ing. G. Kienbaum (Gummersbach) spoke about "The Dependence of Economic Solutions of Bulk Goods Handling upon the Cost Structure." A steel production of 24,000,000 tons necessitated the transport of about 70,000,000 tons of materials such as ore, coke, scrap and limestone. Works railways had a traffic volume of 200 million tons to deal with. It was clear that transport was a main factor upon the price of steel. Optimal solutions of each transport problem could be found only if, in the case of internal transport, costs were assigned to account positions which were identical with the various transport stages. The technical solution for each stage depended upon the whole chain. The speaker showed what the various cost factors were for each stage of the transport of ore, how they could be influenced, and what the consequences were for a future overall solution.

Section 4 : Blast-Furnaces

In this section, the first lecture was "Physical Properties of Coke and their Relation to the Blast-Furnace Process," by Dipl.-Ing. W. Himsel (Duisburg-Huckingen). The speaker described an experiment carried out over six weeks on a blast-furnace with a hearth diameter of 6·1m, which showed that mechanically stronger coke was correlated with higher output. Dipl.-Ing. V. Steinecke (Düsseldorf), speaking about "The Mathematical-Statistical Evaluation of Blast-Furnace Characteristics," showed how factorial analysis of up to fifteen factors and including many blast-furnaces, enabled the effect of individual factors to be determined, together with an estimate of the accuracy of the calculation.

Dr.-Ing. R. Mintrop (Rheinhausen) dealt with the topic "Lower Coke Consumption and Increased Crude Iron Output through Ore Preparation." There were three methods for increasing blast-furnace output which had already been tested on a large scale, i.e. operation under high pressure, oxygen-enriched blast and steam, and the preparation of the charge. Whereas the first two methods increased the output, but left the coke consumption per ton unchanged, the third method—of crushing the ore to the metallurgically and thermally optimum size, with removal and sintering of the fines—not only increased output, but also led to an economy in coke consumption. Since the overall thermal efficiency of a modern blast-furnace fed with an unprepared charge was already over 90 per cent, there was hardly any overall thermal gain, but less of the valuable metallurgical coke was used, at the expense of blast-furnace gas, and the coke fines and other inferior fuels used in the sintering plant. The method of ore preparation had been introduced also in the Ruhr, where it was of increasing importance.

Section 5 : Materials

"Structure and Properties of Gas and Salt-Bath Nitrided Layers of Plain and Alloy Steels" was the theme treated by Prof. Dr.-Ing. H. Wiegand and Dipl.-Phys. M. Koch (Darmstadt). Diffusion of nitrogen into the steel surface caused hardening with hardly any distortion. Fatigue resistance and brittleness were both increased. Until a few years ago it was customary to use the salt-bath or gas for low alloy heat-treated steels as well as high alloy tool steels. Nowadays the diffusion of nitrogen was

applied successfully even to plain steels, for improving the resistance to abrasion and fatigue. This is because the nitrogen-rich iron phase at the surface improved the sliding properties and the pressures which developed in the diffusion zone itself increased the fatigue strength.

"The Eutectoid Decomposition of Austenite and the Formation of Carbide in the Heat-Treatment of High Temperature Tool Steels" was discussed by Dr. A. Rose, Dr. A. Schrader and Dipl.-Ing. L. Rademacher (Düsseldorf). Such steels were slow to undergo phase changes, because of their high alloy content. This was shown not only by their good hardenability, but also by their sensitiveness to small changes in the heat-treatment. Thus, in the case of certain high temperature tool steels in the pearlite stage, one had frequently observed ferritic or ferritoid preliminary precipitates, although these steels were super-eutectic, as shown by their content of undissolved carbides, so that the precipitates would be expected to be carbides. It was thus of interest to see how far such transitions could be described as being in quasi-equilibrium. Investigations were carried out by optical and electron microscopy, X-ray and electron diffraction, and by means of electro-chemical analysis. From the results conclusions were drawn as to the progress of the transformation which was compared with that to be expected from fundamental and equilibrium considerations. It appeared that pre-eutectoid ferritic precipitates in super-eutectic steels could be a consequence of the inhomogeneity of the austenite. Eutectoids with very finely divided carbide phase could not always be distinguished under the microscope from ferrite. The pre-euctectoid precipitation of carbide was often suppressed by supercooling. The isothermal process in the pearlitic range could in general be explained in terms of eutectoid decomposition or peritectoid transitions. Carbide phases formed do not always in amount and composition correspond to those obtained under equilibrium conditions. Such conditions could be reached by way of unstable intermediate stages or through composition changes in carbides which had already formed.

The meeting of Section 5 concluded with the lecture by W. Koch, A. Schrader, A. Krisch and H. Rohde (Düsseldorf) on "Structure Changes of Austenitic Heat-Resisting Steels Through Stresses Applied While at High Temperatures." The speakers described experiments with 18 per cent Cr. and 10 or 12 per cent Ni, as well as a certain percentage of molybdenum, niobium or tantalum; the object being to discover any structure changes under long-term steady loads at 600 deg., 650 deg. and 700 deg. Cent., and to relate these changes to the mechanical behaviour under those conditions. Periodic electron-microscopic examinations showed that at first an increasing amount of carbide was precipitated at the grain boundaries and within the crystallites. Later on there formed at the grain boundaries the sigma-phase as well. Electrolytic analysis enabled the precipitates to be uncovered and their chemical composition, structure and distribution to be determined. The precipitates form at an increasing rate as the stresses and temperatures increase. A comparison between precipitation and mechanical properties in creep tests showed that these phenomena were closely correlated.

General Members' Meeting

On October 25, the 139th members' meeting in the ninety-seven-year-old history of the V.D.E.H. was opened in the largest hall in Düsseldorf, the Apollo Theatre, under the chairmanship of Prof. Dr.-Ing. H. Schenck (Aachen). After re-election of the outgoing committee members and election of new members, the Association's general secretary, Dr.-Ing. K. Thomas, spoke about "The Activities of the Verein Deutscher Eisenhüttenleute." The speaker first referred to the Association's journal, *Stahl und Eisen*, which attempts to report all important events in the iron and steel field. This involved the constant surveying of, and abstracting from, 576 journals, of which 244 were foreign ones. In spite of all efforts at conciseness, the bulk of *Stahl und Eisen* promised to reach a new post-war record this year. A new approach to one aspect of the problem of the excessive growth of scientific literature had recently been made by the Deutsche Forschungsgemeinschaft in conjunction with the German library in Frankfurt/Main, in establishing an archive for valuable unpublished scientific manuscripts.

Most of the Association's work was carried out by the various sections, which in the period January 1 to September 30 had held no less than 320 meetings with a total of about 10,000 registered participants. The sectional committees have a membership of 500, or 1400 if sub-committee members are included. A critical problem was that of patents. At present 165,000 patent applications were waiting to be dealt with at the German Patent Office. More restraint on the part of all concerned was called for, since indiscriminate chasing after patents and priorities was a danger to scientific co-operation.

Dr.-Ing. P. Rheinländer (Salzgitter-Drütte) then spoke about "Lines of Development of Modern Steel Technology." By 1960 an annual German crude steel production of 29,000,000 to 30,000,000 tonnes was planned, requiring annual investments of approximately DM.1000 million. The speaker reviewed the various aspects of the industry in which these investments were required, taking the post-war reconstruction of the Salzgitter works as an example. Professor Dr. E. von Holst (Seewiesen/Obb) gave the second lecture, entitled "Common and Distinguishing Aspects of Man and Animals."

The president, Prof. Dr.-Ing. H. Schenck, in concluding the meeting, spoke about current economic problems of the industry. Referring to the recent increase in the German coal prices, the speaker emphasised that no increases in the iron and steel prices had taken place as a result, in order to oppose inflationary tendencies from the start. German prices for rolled products were below, and in many cases substantially below, those of the other Coal and Steel Community countries. The same was true in relation to Great Britain and the U.S.A. with the exception of thin sheet, for which those countries had erected highly modern single-purpose plants. They also had better depreciation conditions, about which the struggle in Germany was still continuing. Foreign higher prices did not necessarily correspond to higher production costs; in all the other countries one or more of the basic materials, ore, coal, and scrap, was actually cheaper than in Germany. This enabled the accumulation of reserves from profits. Higher prices abroad helped to make up for the lower yield from German home sales, in fact they were the fact which enabled certain enterprises to be run at a profit at all. The development of German steel prices was thus closely linked with the trend of the foreign market; this could hardly give the German steel industry a feeling of security.

Since the previous annual meeting price increases for raw materials had amounted to about DM.300 million for coal and an equal amount for ore and scrap. The iron and steel industry had been kept fully occupied with the task of absorbing these cost increases. It was better to keep down prices than to pay out savings in the form of wages.

A long-term objective was to create specialised undertakings with large and continuous production programmes, as had been done in Britain and America. Such works were very sensitive to economic conditions and for protection had to be combined with similar enterprises working on a different programme. Among major investments was the creation of new sources of raw materials, e.g. in Salzgitter, but also in Africa (in conjunction with other European partners). Finance remained a serious problem. In the last instance this was a question of confidence. Not every momentary slowing down or temporary reverse should give cause for doubts; the overall curve had also been a rising one. Co-operation with consumers was of the utmost importance. A recent illustrative example was the reduction of the number of rolled sections produced from 5211 to 1171 dimensions for sections, and from 3544 to 596 for hot-rolled flats. If the industry were to meet the rising demand, not only the technical but the mental effort involved must be rationalised (e.g. by the expansion of the works in the direction of larger but simplified production programmes).

Frankfurt Airport Extension

Following the opening of the new extension to its northern runway, the Rhein–Main Airport at Frankfurt-on-Main has become the first German airport to fulfil the ICAO requirements for class A. The addition to the north runway is 870m long and increases the total length to 3000m. For the coming jet airliners, a further 600m extension will be necessary, so as to bring the overall length to 3600m. This, however, will not arise until 1958 or 1959.

The present extension necessitated the resiting of three high-tension transmission lines to the west of the airport. A 550m long section of the new runway was begun last winter, a gap of about 300m being left between the end of the existing runway and the new section. During the construction of the gap section the runway had to be closed for four weeks, and all traffic had to use the south runway. For the rapid refuelling of long-distance jet airliners, which require 70,000 to 80,000 litres of fuel, a refuelling rate of about 5000 litres per minute is required, which exceeds the capacity of tanker lorries. It has therefore been decided to construct a pipeline system which is to be ready by next autumn and will cost Dm.2,500,000. It will be built by Esso A.G., Hamburg, which completed a similar installation in 1955 at Stuttgart, and another a few months ago at Munich–Riem. In addition to the existing Esso storage capacity at Frankfurt of 360,000 litres of petrol, a second underground dump for two kinds of turbine fuel is to be built. It is to have a total capacity of 1,000,000 litres and will be supplied from the edge of the airfield by two pipelines. A further 100,000 litres are to be stored in tanks.

The storage dump will be linked by pipes with ten parking places for short and medium range turbo-jet aircraft, each parking place getting one delivery point. There will be four parking places for jet airliners, each being served by two pipelines and having four delivery points. The reason for providing storage for two kinds of fuel is that short and medium-distance air liners use kerosene with a pour point of −40 deg. Cent., whereas military aircraft use JP-4 fuel with a pour point of −50 deg. Cent. It is expected that airliners using the transpolar route will also prefer the low-temperature fuel. Tanking of a large jet aircraft will be done with the "servicers," i.e. mobile units containing pumps, filters, and air separators, each having a pumping capacity of 2500 litres per minute. In this way the overall refuelling time, including preparations, will be of the order of twenty minutes.

Nuclear Marine Propulsion in France

In order to further the application of nuclear energy to the propulsion of ships, a design competition was inaugurated at the beginning of this year jointly by the French Atomic Energy Commissariat and the State Secretariat for the Merchant Navy. Firms taking part belong to the France-Atom and Indatom study groups, which were the first French industrial groups of this kind to be formed. The competition committee sits under the chairmanship of Monsieur Blancard, Director of Liquid Fuels at the State Secretariat for Energy, and among the members are Monsieur Poirier, Director of Economic Affairs and Naval Supplies of the Merchant Navy, and Monsieur Yvon, Director of the Reactor Study Department of the Atomic Energy Commissariat.

It is the object of the competition to produce a design for a nuclear-powered tanker of 40,000 gross tons and 20,000 h.p. Such a vessel is thought to be of sufficient size to be significant for the future without being too expensive. The reactor designs which are being considered are of three kinds: the pressurised water reactor, the boiling water reactor, and the gas-cooled reactor.

The competition is not limited to questions of design, but the projects are to be based on considerations of economy and competitiveness. Safety at sea and in port is also to be investigated. The competing design teams work in collaboration with the Commissariat of Atomic Energy, which is supplying technical data. It is the intention to follow up the design work with the construction of a prototype vessel.

Richmond - San Rafael Bridge

BY OUR AMERICAN EDITOR

No. III—(*Continued from page 691, November 8*)

The Richmond-San Rafael Bridge connecting the towns of Richmond and San Rafael across the northern part of the San Francisco Bay in California, was opened to highway traffic on September 1, 1956. The main structure has a length of 21,343ft. A main and a secondary channel are each spanned by a three-span structure with, in each case, a 1070ft main span and two 535ft spans; vertical clearances above the channels are 185ft and 135ft respectively. Initially, only the upper deck of 36ft width was opened; the lower deck, also of 36ft width, was completed in August, 1957, and the bridge now has six 12ft traffic lanes in operation.

SUBSEQUENT to pile driving and grouting, the shell sections and the initial or 5ft lift of tremie concrete was placed. Check levels indicated that the grouted H-piles and the false timber piles carried the loads imposed without measurable settlement. The floating equipment for the pile driving described included two large, specially-built pile drivers with towers 80ft high which supported leads 124ft in length under the head block. These heads each had a telescopic section which extended to 90ft below water in the plumb position and were limited to 60ft below water in the 1 : 4 batter position. Long piles, which had been driven in very considerable lengths of as much as 194ft, were placed in position and allowed to run down, as far as possible, by their own weight, into the softer clays and silts. Then, if necessary, to get them under the hammer, the hammer was tied on to the pile to provide the additional weight needed to bring its top below the maximum permissible height of 106ft above the water surface.

The bottom 9ft portion of each bell was a precast concrete cylinder with the outside diameter of the designed pier; the base grids were slightly larger in diameter. The cylinder sections were cast at the Petaluma yard and transported by barge to the pier sites. They were similar to units of reinforced concrete pipe, had a wall thickness of 7½in, and had external diameters ranging from 14ft to 34ft. The largest lower shell section weighed 46 tons. To place and centre this section on the base grid, a three-legged lifting tower of latticed steel pipe, which was braced at the top, was bolted to the shell. The length of each tower was such that its top was at approximately 20ft above the water surface when the shell was in its final position. A floating derrick lifted the shell and placed it on the grid. The tower, in addition to serving for the lifting operation, was also used to centre the shell on the grid. Subsequently, after the adjacent shell and tower were placed, the two towers were joined at the top by a truss, and then utilised to support the tremie pipes for the first 5ft lift of concrete; finally, these towers served to align and to brace the upper shaft shells of precast concrete to elevation plus 5ft and to support the tremie pipes for placing concrete in the shells and connecting diaphragms.

The lower precast concrete shells, containing the pier reinforcing, were positioned on the grids as noted. If necessary, the shells were shimmed to a level position and any opening between the shell and its grid was sealed. Following this operation, all deleterious or foreign material was removed from the interior cylinder walls, from the steel H-pile surfaces, and from the precast concrete grid. Such foreign materials were sands and silts or marine growths; each tends to destroy bond between the tremie concrete and the other pier elements. Tremie concrete was then placed for the 5ft lift above the base grids as described previously. Following these operations, common in principle to all bell piers, construction procedures above the lower shell sections varied materially between the two-bell and the four-bell piers. The differences were due to many factors, including the increased weight of the four-bell pier units and are described as follows.

For the two-bell piers the approved construction procedure above the lower shells included three general phases of work. In the first phase, two hollow, tapered shell sections and a connecting diaphragm were precast at the Petaluma yard, taken by barge to the site, and placed as a unit. Next, above the tapered sections precast cylindrical shafts, ranging from 6ft to 14ft in external diameter, were placed separately, aligned, and held by ties to the three-legged towers. It is worthy of note that the longest shaft was 46ft in length and weighed 95 tons. With the shafts in place, removable diaphragm moulds were constructed between them. In the third phase, one tremie pipe was placed in each shaft and one in the diaphragm wall. Following cleaning, tremie concrete was deposited from the initial 5ft lift to elevation plus 5ft.

The approved construction procedure for the four-bell cantilever piers above the lower shells was also in three general phases. In the first phase, the four tapered sections, from 34ft to 12ft in diameter, and their connecting diaphragms, were constructed by the use of expendable steel moulds. The moulds made of thin steel plates reinforced by angle sections were fabricated at the Basalt Rock Company's works near Napa, California, as a unit for each pier, brought by barge to the site, and placed by floating derricks. Each unit included the pier reinforcing steel held in position by clips, or racks, to the steel moulds. Next above the tapered sections, two units of similarly constructed steel moulds, with their reinforcing steel, were fabricated to extend to four 12ft diameter shafts and their 4ft width diaphragm walls to elevation plus 5ft. Again, barges brought the units to the site, then placed by floating derricks, and bolted together by divers. In the third phase, tremie pipes were placed in each of the four bells and at intervals in the diaphragm walls, and concrete was deposited to elevation plus 5ft. Concrete above elevation plus 5ft was placed in the dry.

Ancillary Operations

Due to the character and magnitude of the work it was necessary for the contractor to secure equipment and materials from widely separated areas in the United States. In addition, the contractor also had to arrange for the deliveries of these items to the site, or to local yards, at times required in accordance with the specified schedule. For example, special moulds for the large precast concrete units were designed and fabricated in the Middle-West. Derrick and pile driver equipment was received from the north-west. Other special items came from the eastern States, including the steel H-piles. The manufacture, delivery and handling of these steel H-piles were major items of work in the contract. The bridge contains 5063 steel piles—25,000 tons of steel, with a total footage exceeding 557,000 lineal feet. Rolling mills in the east were the only ones equipped to roll the required section at the rates necessary. The steel H-piles from the Great Lakes region were shipped by rail directly to Oakland. From further east, the piles went by rail to Philadelphia, or to Baltimore, and thence by ocean shipping to San Francisco for final delivery by rail to Oakland.

Piles received in Oakland, at the yard of Gilmore Fabricators, Incorporated, were unloaded, sorted and stacked according to length. Three sets of splicing jigs had been built into which the rolled lengths of steel H-pile sections were placed and spliced by welding to produce the requested driving lengths. As piles were ordered from the site the required lengths were taken from stock, or directly from the splicing jigs, and delivered to the dock, where they were loaded on to a barge and towed to the pier site. The yard utilised for pile splicing and storage was a wartime shipbuilding installation and was well equipped with gantry cranes to handle piles to any part of the yard. Materials passing through the yard followed a direct flow path from rail unloading to storage, or splicing and to loading. To transport piles exceeding 120ft in length the contractor obtained two U.S. Navy "Medium Landing Ships" (LSM), which were converted to cargo barges with a clear deck length of 185ft.

The precast units for the piers, as noted previously, were made at the contractor's yard in Petaluma, which he had used for some time to precast concrete sections for previous work. The facility had been revised and expanded to handle the work for this contract. The yard was divided into two working areas with adequate foundations on which to precast the required sections. A gantry crane spans the width of each yard and is carried on steel rails which are extended out over the water on pile trestles to permit transfer of precast units to barges. In the north yard were cast the mats, the smaller diameter shaft sections on a horizontal position and the tapered and diaphragm sections for the 100ft span bell piers. The south yard was devoted primarily to casting the 9ft height lower shell sections. The larger tapered and diaphragm sections and the larger horizontal shafts were precast on barges.

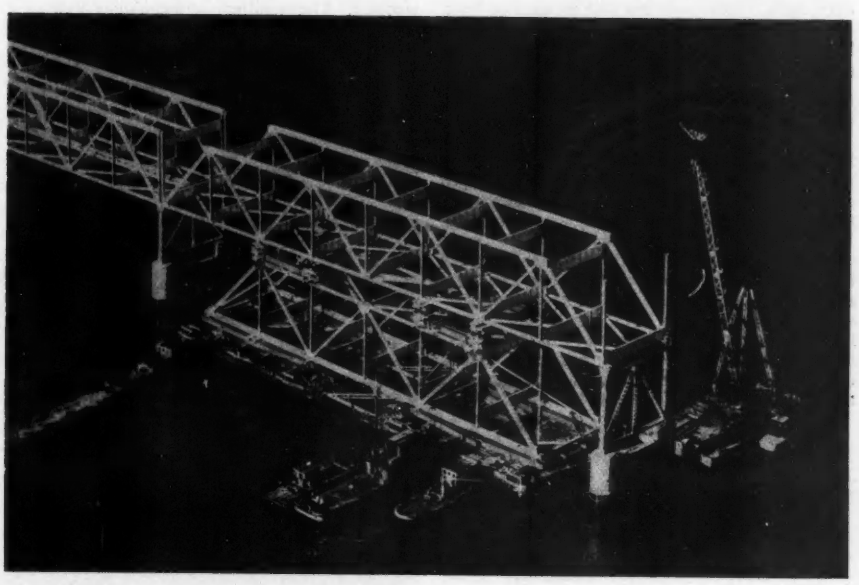


Fig. 9—Erection of 289ft truss span with the aid of an aluminium falsework truss and a floating crane

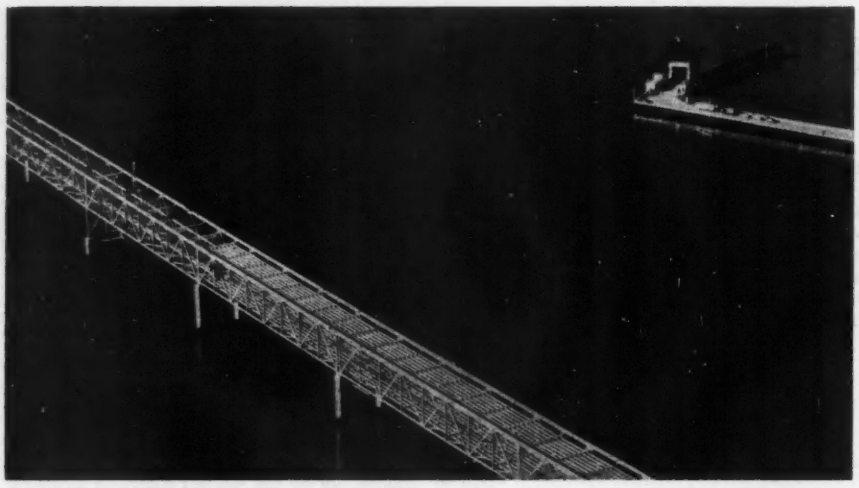


Fig. 10—Erection of deck stringers and minor structural members in upper and lower decks of 289ft truss spans

The bell piers involved nearly 71,000 cubic yards of tremie concrete placed under water and 16,500 cubic yards of conventional concrete placed above water. Concreting was centred on the contractor's floating batching and mixing plant, the "Pacific Mixmaster," which went into service on September 16, 1953. It was a self-contained batching, mixing and placing unit mounted upon a 39ft by 130ft barge. It provided the flexibility desirable because of the large number of separate pours required at each of the sixty-two bell piers, ranging from as little as 10 cubic yards to as much as 2400 cubic yards. On the "Mixmaster" a Noble batching plant discharged directly into the mixer. The batcher was completely automatic; once the scales and water meter had been set for the mix to be used the operator tripped only one lever to weigh out the proper amounts of sand, rock, cement and water. Another lever discharged the batch directly into a Koehring twin-drum paver mixer.

A petrol-engine-driven crane was mounted upon the deck adjacent to the mixer. Concrete was discharged into a 1½ cubic yard bottom dump bucket, and was lifted by this crane into the tremie hoppers or directly into the moulds. Aggregates were received alongside the "Mixmaster" in balanced barge loads and were loaded into the batch plant bins by another deck crane mounted to the rear of the bins.

The "Mixmaster" had cement silos and water tanks aboard with capacity sufficient to mix from 400 to 600 cubic yards of concrete. During the larger pours these could be replenished from cement barges without interfering with the other operations. Although the full production rate of the plant was seldom usable because of other limiting factors, sustained rates in excess of 90 cubic yards per hour were achieved.

Superstructure Construction

The superstructure contract in the amount of 21,099,000 dollars was awarded to the joint venture of Peter Kiewit Sons' Company, A. Soda and Son, and Judson Pacific-Murphy Corporation, of Emeryville, California, in February, 1953. It provided for constructing the 3½ miles of steel spans and supporting towers for the bridge. Included in the contract were the shop and field coat painting of all steel and the construction of the upper deck slab of reinforced lightweight concrete. Excluding the deck, with its 14,000 cubic yards of concrete and 1400 tons of reinforcing steel, the major items of work were as shown in the following table :—

No. of spans	Description	Length, feet	Weight, short tons
36	100ft plate girder spans	3,628	2,500
36	289ft truss spans and bents	10,583	26,100
2	2145ft cantilever spans and towers	4,290	19,800
	Totals	18,501	48,400

The above total of 48,400 tons contains 7475 tons of steel for the subsequent lower deck, which were added to the contract by agreement with the contractor, at his low bid price per pound of carbon steel. This unit price was 25 per cent less than that of the next lowest bidder. The saving to the State of California by adding the lower deck steel to the contract proved to be considerable.

The bridge was designed with various weights and classifications of structural steel, including carbon, silicon, and manganese-vanadium steels as well as heat-treated steel eyebars. It therefore became necessary for the contractor to consider the availability and the capacities of mill and fabricating works to supply the required steel to meet the erection schedules.

The entire superstructure work enjoyed an unusual position in that the administration, the major fabrication and the erection were under the control of one company, although the work was technically a joint venture. The prime contractor followed the policy of sub-contracting the less complicated portions of the fabrication to other works and devoting his time and facilities to the overall planning and to the preparation of equipment for the "mass production" of the trusses for the 289ft spans and the two cantilever spans. Because of the magnitude of the project, involving large tonnages of steel and numerous identical spans, the contractor had the opportunity and incentive to develop original and ingenious schemes for the fabrication and erection of the superstructure steel. The unprecedented use of aluminium falsework trusses, which is described in more detail below, marked an important advance in the field of bridge erection. The facilities and techniques developed to fabricate the seventy-two trusses for the thirty-six identical 289ft spans are also worthy of special mention. As far as erection was concerned this phase of the work was closely co-ordinated with that of the other contracts. Since the relatively shallow piers at the Richmond end were the first to be completed, steel erection started there.

In addition to the Emeryville works of the Judson Pacific-Murphy Corporation, two additional yards were set up at Richmond, California, especially for the storage, fabrication and erection of the bridge steel. One, known as the "steel storage yard," was considered as a branch of the fabrication works. Here, structural shapes were received, either by rail or by truck transfer from ocean shipments, identification numbers were painted on the steel, and the material was stored in designated places for later transport by lorry to the Emeryville fabrication works. The other yard, known as the "paint and shipping yard," was built solely for the project at a considerable cost to the contractor. In this yard the fabricated members were cleaned, painted and stored until needed for erection. Here also was situated the contractor's field office. This yard covered an area of about 40 acres and was developed especially for the project from rough, ungraded filled land on the Richmond water-front. It was situated about a mile from the steel storage yard. Here the completed members were received, cleaned, shop coated and stored for shipment to the bridge. The equipment used within the painting and shipping yard, for water transportation and for bridge erection, is described below. It can be divided into two classes : (1) special equipment built solely for the project, and (2) stock equipment which is used in ordinary construction projects. The special equipment consisted of two aluminium falsework spans, a tower derrick barge, and two traveller stiff-leg derricks, one for the 289ft spans and the other for the cantilever spans.

The aluminium falsework trusses comprised two identical spans, each 280ft long, 36ft deep, 42ft wide, and weighing 117 tons, equipped with six hydraulic jacks for supporting the steel truss and an end toggle device for deflecting the towers to enter pins under a no-load condition. The spans were fabricated of rolled aluminium alloy structural shapes (Alcoa alloy No. 14S–T6) and assembled with steel rivets. The hydraulic jacks were special high-lift units, each equipped with a mechanical locking device, and provided an 18in lift with a capacity of 150 tons.

Fabrication of Steelwork

The superstructure comprises thirty-six plate girder spans, each 100ft long. The girders are 74in deep and are spaced 25ft apart. The floor beams and walkway brackets are also on 25ft centres. Also required were thirty bents varying in height from 28ft to 143ft, and two braced

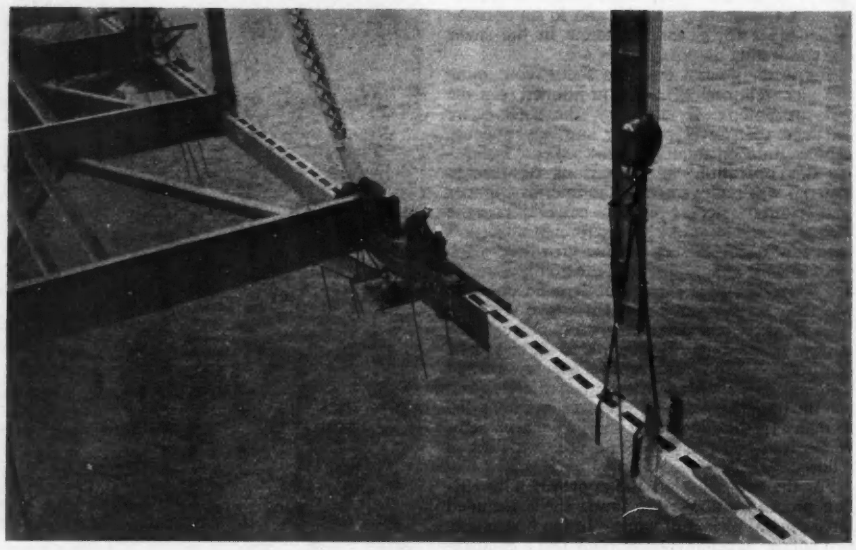


Fig. 11—Closing of cantilever truss span, with member suspended from travelling derrick crane

Fig. 12—This aerial view of the completed bridge structure shows the toll plaza with sixteen lanes in the foreground

towers, at piers Nos. 44 and 30, having heights of 84ft and 117ft. All of these girders, bents, and braced towers were fabricated at the Maywood works of the Consolidated Western Steel Company in Los Angeles. Fabrication followed conventional shop practices and was simplified by the duplication of design details, particularly in the girders and the bracing of the bents.

The thirty-six eight-panel, 289ft truss spans were all similar. The seventy-two trusses were fabricated by the Emeryville works of the Judson Pacific-Murphy Corporation, the floor beams by the Consolidated Western Steel Company in Los Angeles and the stringers and lateral bracing by the Bethlehem Pacific Coast Steel Corporation in Alameda. The fabrication of the floor beams, stringers and lateral bracing followed usual shop practices. The 289ft trusses were fabricated by mass production methods in two operations. First, the built-up members were assembled by conventional methods in the Emeryville shops. They were then moved to the Richmond fabrication yard for the second operation. Here the fabricated built-up members as well as the unit-rolled ones were placed in steel jigs or templates, where end connection holes were drilled. These jigs were the full length of the finished member and were provided with drilling templates for accurately positioning all rivet holes. Each template hole was lined with a hardened steel bushing accommodating the full drill size. Gusset and splice plates were also drilled from master templates. In order to check the drilling templates both for position of joint holes and length of truss members the first truss was horizontally shop assembled and its geometric dimensions checked. The assembled truss fitted perfectly, as all elements of the work had been very carefully performed. This operation verified the accuracy of the jigs and templates for use in drilling the connection holes for the remaining seventy-one trusses.

The cantilever spans and towers, exclusive of eyebars and heat-treated pins, were fabricated at the Emeryville works of the Judson Pacific-Murphy Corporation and at the works of several other local steel fabricators. Pins for the eyebars were forged and heat-treated at the Oakland works of the Moore Dry Dock Company. The cantilever span eyebars were flame-cut full size from special steel flats, were cast, rolled, heat-treated, cut and drilled by the By-Products Steel Company of Coatsville, Pennsylvania. Each completed eyebar was tested for hardness throughout its length. In addition, a test bar, full size except for length, from each melt or furnace charge was tested in tension to destruction. Only the steel from those melts or charges that complied with the necessary chemical and physical requirements was used in this work.

(To be continued)

Long Term Prospects of Rubber

A PROGRAMME of research and development involving the expenditure of £45,000,000 over the next five years was announced by Mr. H. E Humphreys Jr., President of United States Rubber Company, at the opening of the company's new research centre at Wayne, New Jersey. It is to be part of a five years' programme of expanded effort at the research centre and at the company's laboratories at twenty-two locations.

Mr. Humphreys explained the three main objectives of this research programme :

" One of these objectives is to develop passenger car tyres of such superior quality that they will give entirely safe, trouble-free performance at turnpike speeds. Such a tyre at popular prices would permit elimination of the spare tyre on both new cars and used cars."

Referring to the manufacture of three possible tyres of the future, each made with experimental types of synthetic rubber, Mr. Humphreys explained, " each of these experimental tyres has dramatic advantages over tyres available to-day. It is too early to predict if one of these will fulfil our five year goal, or if still another type we have not yet discovered will be the champion. However, we feel confident that we are on the verge of a new break-through toward superior tyre materials, tyre design and tyre construction.

" Another main objective is to bridge the gap between rubber and metals. We are working on a whole new list of rubber types and a whole new list of plastics, as well as blends of the two. These will provide a range of hardness, toughness and ' stretchiness ' all the way from rubber to metals. To-day we are manufacturing a superior blend of rubber and plastics which is stronger than previous types and, in addition, will withstand the higher temperatures required in many uses both in the home and in industry. This development greatly expands the possible use of plastics in piping and promises to make plumbing work simpler and less expensive. We believe this development merely foreshadows a long line of synthetics in the rubber and plastics fields. We have found that our past successes have merely scratched the surface of future possibilities.

" The third objective is to unlock the wealth of atomic energy as it applies to our industry. We have already found ways to use radiation to cure rubber. We see a flood of new materials, including rubber and plastics, resulting from atomic energy. We see entirely new processes in which atomic energy does the work of heat, pressure, catalysts and chemicals. And we are seeking to develop special types of rubber which will stand up under atomic rays at atomic energy plants. In the field of textiles, yesterday there was only one textile, cotton, to reinforce rubber products. To-day, rayon and nylon are the stars. We also use steel wire. Tomorrow, even stronger textiles and wider use of steel and other metals as reinforcing agents will stretch the life of tyres, conveyor belts, industrial hose and other products."

Personal and Business

Appointments

MR. C. T. GOULD has been appointed chief work study engineer of the Reed paper group.

MR. R. B. LAWRENCE has been appointed London sales manager of W. H. Dorman and Co., Ltd.

MR. BENJAMIN R. BEEBEE has been appointed manager of the London office of Henry Meadows, Ltd.

MR. J. W. TIDSWELL has been appointed general manager of Dunlopillo in the Dunlop Rubber Company, Ltd.

VOKES, Ltd., has announced that Mr. D. F. Ringe has been appointed general manager, and Mr. K. D. Mulcaster, chief designer.

THE OWEN ORGANISATION has announced that Mr. Miles Beevor has been appointed a director of Rubery, Owen and Co., Ltd.

INTERNATIONAL PLASTICS, Ltd., has announced that Professor Edgar W. E. Mörath has been appointed director of research and development.

MR. L. A. S. ROBBINS, A.M.I.E.E., has been appointed a director of Duncan Low, Ltd., and will be responsible for and supervise sales in England and Wales.

MR. H. DARNELL has been appointed chief engineer of the Workington Iron and Steel Company in succession to Mr. G. F. Strang, who has left the company to take up another appointment.

THE CENTRAL ELECTRICITY AUTHORITY has announced the appointment of Mr. W. H. Dunkley, M.I.E.E., M.I.Mech.E., as chief generation engineer (operation), Midlands division, as from January 1, 1958. It has also announced that Mr. R. C. Hodson, A.I.E.E., has been appointed generation engineer (operation) of that division.

SIMMS MOTOR UNITS, Ltd., announces the following appointments :—Mr. W. Newland, export manager to Simms Motor Units, Ltd., and to the Simms group of companies, and assistant to the general manager, Mr. J. Ayres ; Mr. N. J. Ellerbeck, commercial manager ; Mr. W. H. Binns, sales manager, operators division ; Mr. D. H. Henri, sales manager, manufacturers division ; Mr. E. Broom, branch controller ; Mr. J. Bell, manager of the Birmingham branch ; and Mr. J. Eite, manager of the Cardiff branch.

Business Announcements

LEWIS BROOKS AND CO., Ltd., announces that it has acquired control of the Hydraulic Engineering Company, Ltd., Chester.

MAJOR FREDERICK MONK, chief safety officer of the Dunlop Rubber Company, Ltd., until he retired in 1952, has died at the age of seventy.

G. MUNCASTER states that it has formed a limited liability company with the title Muncaster Machine Tools, Ltd., and will in future trade under this title.

THE HOFFMANN MANUFACTURING COMPANY, Ltd. Chelmsford, Essex, states that it has opened a new stockroom at 127, Bath Road, Slough (telephone, Slough 22351).

THE DUNLOP RUBBER COMPANY, Ltd., has donated £1000 to the Production Engineering Research Association's fund for the development of a new workshop and laboratory.

RANSOME AND MARLES BEARING COMPANY, Ltd., Newark-on-Trent, states that it has acquired the exclusive British rights for the manufacture and sale of Thomson ball bushings.

STACKHOUSE (LONDON), Ltd., states that it has moved from Ibex House, Minories, London, E.C.3, to the Warehouse, British Railways, Western Region, West Ealing Goods, Old Yard, Ealing, London, W.3.

THE NORTHERN IRELAND DEVELOPMENT COUNCIL has announced that one of the new "advance" factories at present under construction on the Carnmoney Estate, near Belfast, is to be occupied by Belfast Cables, Ltd., a subsidiary company of Reliance-Clifton Cables and Industrial Products, Ltd., Leyton, London. The company will manufacture plastic-covered cables.

GEORGE COHEN, SONS AND CO., Ltd., Coborn Works, Tinsley, Sheffield, 9, has completed the modernisation and extensions to the offices at its Sheffield depot. The offices, which were officially opened on October 29 by Mr. Felix L. Levy, are the headquarters of the company's raw materials division n the north and also include the Sheffield branch of the machinery division.

GEBR. STORK AND CO., N.V., Hengelo, Holland, has announced that it has entered into an agreement with the Wallsend Slipway and Engineering Company, Ltd., in association with Swan, Hunter and Wigham Richardson, Ltd., and Barclay, Curle and Co., Ltd., for the manufacture in the United Kingdom of the Stork single-acting, two-stroke, turbo-charged, diesel engine in a range of horsepowers up to a maximum of 16,000 b.h.p.

AERO RESEARCH, Ltd., honeycomb will, in future, be marketed under the registered trade name of "Aeroweb." Used in conjunction with "Redux" adhesive in film form for the production of sandwich panels, it is suitable for flat surfaces of constant or tapering thickness, as well as for shapes involving single or double curvature. "Aeroweb" honeycomb is supplied in thicknesses up to 9in in cell sizes of ⅛in, ¼in and ½in inscribed circle, and in various foil thicknesses.

HIGGS AND HILL, Ltd., JAMES BURNESS AND SONS, Ltd., THE BRUSH GROUP, Ltd., and BRIAN COLQUHOUN AND PARTNERS, have announced that they have formed a consortium to build a shipyard in Cuba and twenty-five ships for carrying sugar, iron ore, other bulk commodities, and general cargo. These companies, it is stated, have signed a declaration of common purpose with Banco de Desarollo Economico y Social (Bandes) with the co-operation of Banco Cubano del Comericio Exterior. The total cost has been estimated at £30,000,000.

E. I. DU PONT DE NEMOURS AND CO., INC., Wilmington, Delaware, and DURHAM RAW MATERIALS, Ltd., London, have jointly announced modifications in the arrangements under which Durham Raw Materials, Ltd., have been the sole distributors of "Neoprene" in the United Kingdom. The Du Pont Company (United Kingdom), Ltd., 5, Charles II Street, London, S.W.1, has been formed to manufacture and sell "Neoprene" in the United Kingdom and European markets. This company is a wholly-owned subsidiary of E. I. Du Pont de Nemours and Co., Inc., and with effect from January 1, 1958, sales for "Neoprene" will be made in the name of Du Pont Company (United Kingdom), Ltd., and Durham Raw Materials, Ltd., will act as sales agents. With effect from January 1, 1959, Durham Raw Materials, Ltd., will surrender the agency and Du Pont Company (United Kingdom), Ltd., will assume full control of all "Neoprene" sales.

Contracts

HEAD WRIGHTSON AND CO. S.A. (PTY.), Ltd., Johannesburg, has been awarded a contract for the supply of a 16ft diameter blast-furnace, which is part of the expansion programme of the Rhodesian Iron and Steel Company (Pvt.), Ltd., for its works near Que Que, Southern Rhodesia. In addition, the same company has secured the order for a 3,000,000 cubic feet per hour gas cleaning plant required to clean the gas produced by the new furnace and the two smaller existing furnaces. The plant will be to the general design of Head Wrightson Iron and Steel Works Engineering, Ltd., in collaboration with the Rhodesian Iron and Steel Company's consulting engineers, John Miles and Partners, of Bulawayo.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., has received an order for high-frequency radio telecommunications equipments, to a value of nearly £50,000, from the Sudan Posts and Telegraphs Department for the Khartoum Communications Centre. The order includes three 3½kW, h.f. transmitters, type HS31, with their associated drive, keying and monitoring equipments, and a 30kW linear amplifier. Special switchgear will permit the amplifier to be used with any of the transmitters. Six receivers will be supplied, two for independent sideband operation, two for single sideband operation, and two double diversity telegraph receivers, one of which will be adapted for frequency-shift "Diplex" signals.

Miscellanea

INTERNATIONAL NUCLEAR ENERGY EXHIBITION.—A commercially organised international exhibition is to be held at the Palais des Expositions, Geneva, concurrently with the second Conference on the Peaceful Uses of Atomic Energy sponsored by UNO. The Nuclear Energy Trade Associations' Conference (NETAC) announces that it has undertaken to co-ordinate British applications for space. The closing date for booking space is given as November 20, 1957, and the period of the exhibition as from September 1 to 14, 1958. Further information is available from NETAC, 32, Victoria Street, London, S.W.1.

ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—On November 5, Mr. W. Heigh presented his paper "The Geometry of the Job" before the Institution of Engineers and Shipbuilders in Scotland. The paper considers various time-saving methods which can be used in design and drawing-offices, in pattern shops, in mould lofts, and on surface tables and which may contribute to improved productivity in other manufacturing operations. Simple examples in arithmetic and plane geometry are examined, as are also questions related to solid geometry and the range of devices, including charts, scales and formulæ, by which calculations are simplified.

BRITISH NUCLEAR ENERGY CONFERENCE.—At a recent meeting of the board of the British Nuclear Energy Conference, under the Chairmanship of Sir John Cockcroft, the Institute of Fuel was admitted to membership of the B.N.E.C. The purpose of the British Nuclear Energy Conference is to co-ordinate the activities of the constituent members in the field of nuclear energy ; meetings are held and a journal is published. The constituent societies of the B.N.E.C. now number eight, namely, the Institutions of Civil, of Mechanical, of Electrical, and of Chemical Engineers ; the Institutes of Physics, of Metals, and of Fuel, and the Iron and Steel Institute. The offices are at 1-7, Great George Street, London, S.W.1.

FILMS ON CALDER HALL AND DOUNREAY.—Every important stage in the construction of Calder Hall and Dounreay was filmed, and some of the results are now available on loan, free of charge, from Ace Distributors, Ltd., 14, Broadwick Street, Wardour Street, London, W.1. Issued under four titles, these well-produced films show how the erection of the reactors, &c., proceeded, according to a tight schedule, from one planned step to another. "The Construction of Calder Hall" (forty minutes), "Heat Exchangers at Calder Hall" (twenty-eight minutes), and "Engineering at Calder Hall" (thirty-nine minutes), form the trilogy on the civil and structural engineering history of the nuclear power station, and "The Dounreay Sphere" (thirty-five minutes) shows how the great globe for the fast breeder reactor grew, tier upon tier, on a desolate stretch of coastline. The films were made for the U.K. Atomic Energy Authority as part of a training series.

ANDREW LAING LECTURE.—The twenty-sixth Andrew Laing lecture, entitled "The Marine Oil Engine : a Chapter in its Evolution," was read by Mr. C. C. Pounder before the North East Coast Institution of Engineers and Shipbuilders on November 1. The lecture falls into three parts, of which the first is a brief account of the development of the earlier engine designs which were built in Belfast, and of the later designs which were both designed and constructed there. In the second part of the lecture important practical problems dealing with the main engine parts, such as bottom cylinder covers, pistons and piston-rods, bedplates and crankshafts, are stated and a detailed account is given of their elucidation. Typical ways and means to overcome specific difficulties are the subject of the third section and the problems encountered in various adjunctive mechanisms, including dampers, governors and synchronising gear are illustrated and the solutions outlined. The lecture ends with some general observations touching upon similitude and proportion, the importance of finish, and changes in design.

OIL FOR BRITAIN.—At De La Rue House, Regent Street, London, W.1, Thomas De La Rue and Co., Ltd., in conjunction with the Esso Petroleum Company, Ltd., are showing an "Oil for Britain" Exhibition, which opened on November 5 and will close on November 20. The exhibition includes a model of the Esso Refinery at Fawley and also the tanker loading jetty, while various photographs illustrate the wide use of oil, ranging from the major industries to the home. Illustrations trace the operations involved in producing the crude oil and the refined product, and graphs show present and anticipated demand. At a preview of the exhibition a film, "Energy for Europe," was shown and depicted the rise in the demand for power since the turn of the century and the various methods adopted for harnessing power, together with animated diagrams illustrating the expansion required of the oil industry to bridge the gap. Concurrently with the exhibition there is on view a range of "Potterton" oil-fired and gas-fired boilers, including a new oil-fired unit, the COA 53, which is completely automatic and has a rated output of 53,000 B.Th.U. per hour. This model consists of a cast iron sectional boiler with integral draught stabiliser ; a pressure jet burner, which allows the use of 35-second fuel, with photo-electric control and a thermostat. The unit is enclosed in a sheet steel case and is suitable to meet the central heating and hot water requirements of a four-bedroom house.

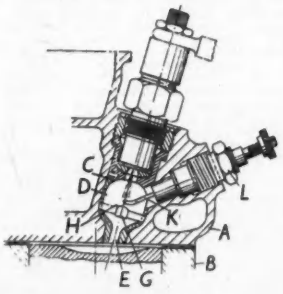
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

INTERNAL COMBUSTION ENGINES

784,481. February 20, 1956.—PRECOMBUSTION CHAMBER DIESEL ENGINES, Daimler-Benz Aktiengesellschaft, Stuttgart Untertürkheim, Germany.

The invention concerns improvements relating to diesel engines which have a precombustion chamber consisting of a wide, approximately spherical, portion and a narrower duct-like portion extending towards the cylinder space, an insert element arranged in the chamber and an incandescent plug. As shown



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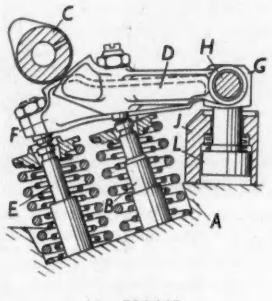
in the drawing, arranged in the cylinder head *A* of an internal combustion engine *B* is a precombustion chamber *C* consisting essentially of a wide, approximately spherical, portion *D* and a narrower duct *E* opening into the cylinder space. At the transition between the portion *D* and the portion *E*, an insert element *G* having a surface *H* of hemispherical or part-spherical shape is arranged centrally on a pin mounted at both ends in the wall of the chamber *C*. The heatable filament *K* of an incandescent plug *L* connected to an automatically opening delay-action switch projects into the wide portion *D* of the chamber *C*. The filament *K* forms a loop above the element *G*, the free end of the loop being disposed in the central longitudinal axis of the chamber immediately above the insert element *G* and normal to the direction of the fuel injection from the nozzle. A part of the jets of fuel issuing from the nozzle strikes the loop of the heated filament *K* and is atomised, vaporised and ignited there. Another part of the jets strikes the element *G* is reflected by its surface *H*, where it is atomised, towards the loop, where it is vaporised. Yet another part of the jets is atomised by the element *G*, but does not strike the loop. If required, the delay-action switch for the plug *L* may be provided with means for setting a longer or shorter period of incandescence of the plug, depending upon the outside temperature or the time of year.—*October* 9, 1957.

784,265. September 13, 1955.—VALVE CONTROL MECHANISM, The Daimler-Benz Aktiengesellschaft, Stuttgart-Untertürkheim, Germany.

The invention relates to valve mechanisms and is concerned with hydraulic adjusting devices for eliminating slackness or clearance. As shown in the drawing, the cylinder head *A* of an internal combustion engine has a valve stem *B*, which is actuated from a camshaft *C* through a rocking lever *D* and another valve stem *E* which is actuated by a rocking



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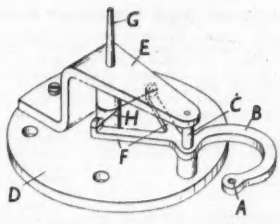
lever *F*. The lever *D* is rockable in a fork bearing *G* about a pivot pin *H* and the lever *F* is similarly mounted. The fork bearings and a bearing bracket *J* carrying them, are secured to the cylinder head with a gasket and form parts of the hydraulic adjusting device. The fork bearing *G* is, it will be seen, supported by a spring-loaded ram or piston *L* slidable in the bearing mounting *J*. In the event of any clearance between the valve stem *B* and the rocking lever *D* and the main circular part of the respective cam, the spring presses down the piston *L*, and hence the fork bearing *G*, until clearance is eliminated.—*October* 9, 1957.

MEASURING INSTRUMENTS

784,216. January 6, 1954.—PRESSURE GAUGES, Measurement, Ltd., Terminal House, Grosvenor Gardens, London, S.W.1. (*Inventor: Frederick Cecil Zula Crosse.*)

The invention relates to pressure gauges in which the movement of an actuating member is converted into rotary movement of an indicating spindle carrying a pointer associated with a scale. The invention is



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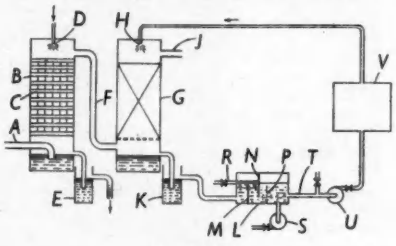
illustrated in the drawing, which shows a Bourdon pressure gauge. The moving end of the Bourdon tube is connected by a link pivoted at *A* to one arm *B* of a lever carried on a short spindle *C* pivoted between a base-plate *D* and a bracket *E*. The other end of the lever is bifurcated, the two prongs *F* thus formed being splayed outwards to project on either side of the pointer spindle *G*. A length of nylon *H* is wrapped around the pointer spindle and the two ends are connected to the ends of the prongs. Thus, as the lever is moved by the link, the pointer spindle is rotated, converting the linear movement of the link into a rotary movement of the pointer spindle. Preferably, as shown, the thread, before being wrapped round the spindle, is threaded through a hole or eye in the spindle. Preferably also spring means are provided for maintaining slight tension on the nylon thread. A modified construction is also shown in the specification.—*October* 9, 1957.

GASEOUS FUELS

784,524. November 12, 1954.—MANUFACTURE OF COMBUSTIBLE GAS, Humphreys and Glasgow, Ltd., Humglas House, 22, Carlisle Place, Westminster, London, S.W.1.

The invention is concerned with the manufacture of combustible gas, and relates to the cooling of such gases of the type from which, in the final stages of cooling, viscous tars and maybe also solids, such as carbon and naphthalene may separate out and adhere to the walls of the vessels and of the outlets provided



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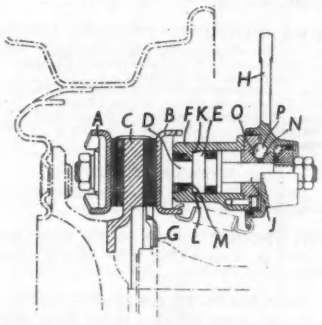
for the gas and the cooling liquid. The object of the invention is to achieve the secondary cooling of a combustible gas by direct contact with a solvent liquid, such as a tar fraction, after preliminary cooling of the gas has first been effected with water, the solvent liquid being itself then cooled and otherwise reconditioned for re-use and circulated for further secondary cooling. As will be seen from the drawing, the hot tarry make gas from the oil gas generator is passed, first, through an inlet pipe *A* into a washer scrubber *B*, in which the gas passes, first, through a water seal and then rises through wood grid packing *C* countercurrent to water introduced from sprays *D* at the top of the scrubber shell. Water from the sprays, together with tar and solids that have separated out from the gas, passes through a seal pot *E* of the usual type to tar settling and separating plant, while the partially cooled and partially detarred gas is passed through a conduit *F* to a secondary scrubber *G* filled with suitable packing, such as ceramic raschig rings. The gas enters the base of the secondary scrubber into the top of which creosote is sprayed downwardly over the packing by sprays *H*. The cooled gas leaves the top of this scrubber and passes through a conduit *J* for subsequent treatment, such as removal of tar fog, followed by purification and storage, while the creosote, together with water condensed from the gas, passes via a seal pot *K* into a settling tank *L*. In the settling tank, which may be fitted with a baffle *M*, the water separates out on one side of a skimmer plate *N*. The creosote flows under the plate and then passes through a filter screen *P* beyond which it is drawn from the tank for cooling and treatment prior to being returned to the circuit as set out below. The water is conveniently run off periodically from a drain *R* set at a suitable working height. A minor part of the creosote is drawn off from the settling tank *L* by a pump *S* into a still, wherein it is heated and then steam distilled, steam-volatile materials, such as naphthalene and benzole, being thus removed, while the treated creosote flows into a second settling tank, where any water conveyed with it from the steam distillation separates. By means of suitable connections the creosote from this second tank, together with creosote passing through a conduit *T* directly from the first settling tank, drawn by a pump *U*, which passes it first through a water-cooled tubular cooler *V* and thence on to the sprays *H* of the secondary scrubber *G*. Provision may also be made for removing some of the creosote from the first settling tank *L* and using it as fuel for process heating or for steam raising. Fresh creosote is added to the circuit to replace it and this is a means of controlling the amount of tar in the circuit.—*October* 9, 1957.

POWER TRANSMISSION

784,887. July 7, 1955.—"SPOT TYPE" DISC BRAKE, Heinz Teves and Ernst August Teves, trading as Alfred Teves Maschinen- und Armaturenfabrik Kg., of 41–53, Rebstöcker Strasse, Frankfurt/Main, Germany.

The invention relates to a "spot type" disc brake, which can be arranged in small wheels. It differs from other forms of construction in that instead of a saddle made of light metal provided with lining segments of friction material and embracing the rotary disc, two sheet metal pressure plates are used as lining carriers. As will be clearly seen from the drawing, the two pressure plates *A* and *B* are arranged on both sides of the brake disc *C*. The lining pressure plate *A* is fitted at one end to a pin *D* which is fast with the piston *E* in the wheel brake cylinder *F*, and slidingly supported in the brake carrier *G*. The hand brake lever is pivoted on the piston rod *J*. The piston is provided with chamfered portions *K*. The annular space *L* thus formed is filled with pressure means when the brake is operated. The brake is also provided with a second brake wheel cylinder similar



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to cylinder *F*, acting on the other end of the pressure plate *A*, the cylinder being fitted with a similar hand brake lever. To operate the brake pressure fluid is fed into the annular space *L*, and the pressure which builds up there acts on the piston *E* and displaces it to the right, thus also the pin *D*, which causes the brake lining carried by the pressure plate *A* to be pressed against the brake disc *C*. The pressure simultaneously acts on the annular surface *M* in the housing of the brake cylinder *F*. The wheel cylinder housing, arranged in axially movable manner on the piston rod, is displaced by the pressure developed in the direction of the brake disc *C*, which causes the brake lining carried by the pressure plate *B* attached to the brake cylinder to be pressed against the brake disc. In addition to the hydraulic brake, a mechanical brake in the form of a locking hand brake is arranged. The wheel brake cylinders and brake levers are provided on one side with conical cut-outs *N* and *O*, and communicate via the ball *P*. Mutual rotation of the two parts causes the balls to run up the oblique portions, so that the two brake plates are pressed against the brake disc.—*October* 16, 1957.

Launches and Trial Trips

ROCKHAMPTON STAR, refrigerated cargo ship; built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for the Blue Star Line, Ltd.; length overall 507ft 2in, breadth moulded 68ft, depth moulded 41ft 6in, draught moulded 27ft 6in; six passengers; service speed 17½ knots; two continuous decks, five holds, derrick complement to lift 3, 5, 10, 15 and 50 tons, electric winches; four 300kW diesel driven generating sets; Harland and Wolff, single-acting, two stroke, turbo charged diesel engine, eight cylinders, 10,000 service b.h.p. at 107 r.p.m., equipped to burn heavy fuel oil. Launch, September 24.

BRITISH HONOUR, oil tanker; built at Belfast by Harland and Wolff, Ltd., for the B.P. Tanker Company, Ltd.; length between perpendiculars 630ft, breadth moulded 85ft 6in, depth moulded 46ft 8in, deadweight 32,000 tons; thirty oil cargo compartments, one main cargo pump room, two 600kW, 440V 60 c/s geared turbo-alternators, one 75kW steam driven alternator, one 150kW diesel driven alternator; one set of compound double reduction geared turbines, 14,000 service s.h.p. at 105 r.p.m., two Babcock and Wilcox integral furnace boilers supply steam at 600 lb per square inch and 850 deg. Fah. Launch, September 25.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Nov. 15.—OXFORD, READING AND DISTRICTS BRANCH: Regent's Park College, Pusey Street, Oxford, "Transformer Construction and Design," 7 p.m.

Tues., Nov. 19.—LONDON NATIONAL LECTURE: Magnet House, Kingsway, London, W.C.2, "Special Effect Lighting," W. R. Stevens, 6.30 p.m. ★TYNESIDE BRANCH: Crown Hotel, Clayton Street West, Newcastle, "A Brief Survey of Metal Rectifiers and their Applications in Industry," J. Bulman, 7.30 p.m.

Wed., Nov. 20.—NOTTINGHAM BRANCH: East Midlands Electricity Board's Showroom Theatre, Smithy Row, Nottingham, "The Search for Undersea Coal Reserves," W. H. Brooks, 7.30 p.m.

Thurs., Nov. 21.—KENT BRANCH: Rose and Crown Hotel, Tonbridge, Kent, "The National Inspection Council," and "I.E.E. Wiring Regulations," E. J. Sutton, 7.30 p.m.

Fri., Nov. 22.—STOKE AND CREWE BRANCH: Grand Hotel, Hanley, Stoke, Film, "Cables Round the World," 7.30 p.m.

BRITISH COMPUTER SOCIETY

Mon., Nov. 18.—L.C.C., County Hall, London, S.E.1, "Applications of a Computer to the Work of Norwich Corporation and Plans for Future Use," A. J. Barnard, 6.15 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Nov. 21.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "U.H.F. F.M. Transmission," H. V. Sims, 7 p.m.

Fri., Nov. 22.—MERSEYSIDE SECTION: Technical College, Birkenhead, "Tropospheric Scatter System Evaluation," M. Telford, 7 p.m. ★SCOTTISH SECTION: Department of Natural Philosophy, The University of Edinburgh, "U.H.F. F.M. Transmission," H. V. Sims, 7 p.m.

CHEMICAL SOCIETY

Thurs., Nov. 21.—Burlington House, Piccadilly, London, W.1, Meeting for the reading of original papers, 7.30 p.m.

DIESEL ENGINEERS AND USERS ASSOCIATION

Thurs., Nov. 21.—Caxton Hall, Westminster, London, S.W.1, "Fuel Injection Equipment," G. R. Green, 2.30 p.m.

INCORPORATED PLANT ENGINEERS

Wed., Nov. 20.—KENT BRANCH: County Hotel, High Street, Ashford, "Clutches," E. Whiteley, 7 p.m

Thurs., Nov. 21.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "The Heat Pump," A. W. Bates, 7.30 p.m.

Mon., Nov. 25.—WEST AND EAST YORKSHIRE BRANCH: The University, Leeds, "Nuclear Reactors for Power Production," J. A. Dixon, 7.30 p.m.

INDUSTRIAL WELFARE SOCIETY

To-day to Mon., Nov. 15 *to* 18.—Grand Hotel, Brighton, Conference on "Trends in Apprenticeship Training."

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Nov. 19.—E. ANGLIAN SECTION: Public Library, Ipswich, "Effect of Moulding Methods on the Physical Properties of Sand Moulds," W. B. Parkes, 7.30 p.m.

Wed., Nov. 20.—LONDON BRANCH: Constitutional Club, Northumberland Avenue, London, W.C.2, "Safety in the Foundry," H. Paton Millar, 7.30 p.m. ★SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Birth of a Bell," D. Hughes, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Wed., Nov. 20.—MERSEYSIDE AND N.W. SECTION: Technical College, Birkenhead, "Engine Room Equipment," J. N. Cairns, 7.15 p.m.

Thurs., Nov. 21.—KINGSTON UPON HULL AND E. MIDLANDS SECTION: The Royal Station Hotel, Kingston upon Hull, "Marine Lubrication," G. H. Clark, 7.30 p.m.

Fri., Nov. 22.—MERSEYSIDE AND N.W. SECTION: Technical College, Bolton, "Engine Room Equipment," J. N. Cairns, 3 p.m. ★SOUTH WALES SECTION: Swansea Technical College, Mount Pleasant, Swansea, "Modern Marine Steam Turbines," J. H. Gooch, 2.15 p.m.

INSTITUTE OF METALS

Thurs., Nov. 21.—BIRMINGHAM LOCAL SECTION: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Metallurgical Thermodynamics," J. N. Pratt, 6.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Nov. 15.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Doppler Navigation," G. E. Beck, C. M. Moorhen, P. Houghton, C. S. Hurst, D. O. Fraser and T. Gray, 5.15 p.m.

INSTITUTE OF PHYSICS

To-day, Nov. 15.—S. WALES BRANCH: University College, Swansea, "Atomic Clock," L. Essen, 5.15 p.m. ★NON-DESTRUCTIVE TESTING GROUP: The University, Sheffield, "The Physical Properties of Glasses and their use in Control Tests in the Glass Industry," R. W. Douglas, 6.30 p.m.

Tues., Nov. 19.—SCOTTISH BRANCH: Department of Natural Philosophy, The University, Glasgow, "Nuclear Power Production," D. C. G. Smith, 7.15 p.m.

Wed., Nov. 20.—YORKSHIRE BRANCH: Physics Department, The University, Sheffield, "The Velocity of Light," L. Essen, 5 p.m.

Fri. Nov. 22.—S.W. BRANCH: Royal Military College of Science, Shrivenham, "The Field Emission of Electrons," F. A. Vick, 7 p.m.

INSTITUTE OF LOAD TRANSPORT ENGINEERS

Mon., Nov. 18.—NORTH REGIONAL CENTRE: Commercial Hotel, Accrington, "Some Notes on Fuel Injection Equipment for Road Transport," J. Skinner, 7.30 p.m. ★SCOTTISH CENTRE: North British Hotel, Edinburgh, "Air Brakes and Auxiliaries for Commercial Vehicles," W. A. Kirk, 7.30 p.m.

Tues., Nov. 19.—NORTH EASTERN CENTRE: Three Tuns Hotel, Durham City, Open Forum, 7 p.m.

Thurs., Nov. 21.—METROPOLITAN AREA: Royal Society of Arts, John Adam Street, London, W.C.2, "The Operation and Development of Disc Brakes," T. J. Phipps, 6.30 p.m. ★YORKSHIRE CENTRE: Great Northern Hotel, Wellington Street, Leeds, 1, "Some Aspects of Vehicle Insurance and Accident Assessment," A. G. Wright, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., Nov. 19.—NORTH WESTERN BRANCH: Reynolds Hall, College of Science and Technology, Manchester, "Pressure Vessels," R. W. Lakin, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, Nov. 15.—Great George Street, Westminster, London, S.W.1, Conference on the Highway Needs of Great Britain.

Tues., Nov. 19.—Great George Street, Westminster, London, S.W.1, "Langstone Bridge, Hampshire," J. W. Melrose and W. A. Eyre, 5.30 p.m.

Wed., Nov. 20.—N.W. ASSOCIATION: 9, The Temple, 24, Dale Street, Liverpool, Chairman's Address, R. Nicholas, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Nov. 18.—MERSEY AND NORTH WALES CENTRE: Royal Institute, Colquitt Street, Liverpool, "Some Aspects of Half-Wave Magnetic Amplifiers," G. M. Ettinger, 6.30 p.m.

Tues., Nov. 19.—MEASUREMENT AND UTILIZATION SECTIONS: Savoy Place, London, W.C.2, Discussion on "The Measurement of the Dynamic Characteristics of Electrical Machines," opened by J. M. Layton, V. N. Manohar and R. A. Stevens, 5.30 p.m. ★EAST MIDLAND CENTRE: Loughborough College, Loughborough, "Design for Production" H. T. Price, 6.30 p.m. ★NORTH MIDLAND CENTRE: Central Electricity Authority, Yorkshire Division, 1, Whitehall Road, Leeds, "Some Aspects of Heat Pump Operation in Great Britain, with particular reference to the Shinfield Installation," M. V. Griffith, 6.30 p.m.

Wed., Nov. 20.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Earthing of Low and Medium-Voltage Distribution Systems and Equipment," F. Mather, 5.30 p.m. ★SHEFFIELD SUB-CENTRE: Grand Hotel, Sheffield, "D.C. Winder Drives using Mercury-Arc Rectifier/Inverters," L. Abram, J. B. McBreen and J. Sherlock, 6.30 p.m.

Thurs., Nov. 21.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "High-Voltage Experiments," opened by E. Bradshaw, 6 p.m.

Fri., Nov. 22.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, Discussion on "Radio Observations on the Russian Satellite," 2.30 p.m. and 5.30 p.m.

Mon., Nov. 25.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "Problems of Sound and Television Broadcasting Coverage," G. Millington, 5.30 p.m. ★EAST ANGLIAN SUB-CENTRE: Assembly House, Norwich, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Garrick, R. G. Hibberd and A. J. Blundell, 7.30 p.m. ★MERSEY AND NORTH WALES CENTRE: Town Hall, Chester, "Earthing of Low and Medium-Voltage Distribution Systems and Equipment," F. Mather, 6.30 p.m. ★NORTH EASTERN CENTRE: Neville Hall, Newcastle upon Tyne, "Electrical Equipment for Rectifier Locomotives," H. B. Calverley, E. A. K. Jarvis and E. Williams, 6.15 p.m. ★SOUTH MIDLAND CENTRE, AND SOUTH MIDLAND RADIO AND MEASUREMENTS GROUP: James Watt Memorial Institute, Great Charles Street, Birmingham, "Magnetic Materials," F. Brailsford, 6 p.m. ★WESTERN UTILIZATION GROUP: South Wales Electricity Board, Swansea, "D.C. Winder Drives using Mercury-Arc Rectifier/Inverters," L. Abram, J. B. McBreen and J. Sherlock, 6 p.m. ★READING: George Hotel, King Street, Reading, "Cathodic Protection," J. H. Gosden, 7.15 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Sat., Nov. 23.—N.E. BRANCH: Visit to Associated Lead Manufacturers, Ltd., Elswick, Newcastle upon Tyne, 10 a.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Nov. 19.—39, Elmbank Crescent, Glasgow, "Recent Developments in Cycloidal Propellers," E. C. Goldsworthy and W. Betts Brown, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Nov. 20.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Vibrational Aspects of Bogie Design," J. Koffman, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 15.—THOMAS HAWKSLEY LECTURE: 1, Birdcage Walk, Westminster, London, S.W.1, "Vibration: A Survey of Industrial Applications," J. P. den Hartog, 6 p.m. ★SCOTTISH BRANCH: Robert Gordon's College, Aberdeen, "Recent Developments in Propulsion Machinery and Refrigeration Equipment for Deep Sea Trawlers," G. C. Eddie, 7.30 p.m.

Mon., Nov. 18.—EASTERN BRANCH: Lecture Theatre No. 1, Engineering Laboratory, University of Cambridge, Trumpington Street, Cambridge, "Vibration: A Survey of Industrial Applications," J. P. den Hartog, 7.30 p.m. ★DERBY A.D. CENTRE: Midland Hotel, Derby, "Some Experiments with Internal-Combustion Engines," R. C. Cross, 7.15 p.m. ★SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Servicing the Modern Vehicle," A. D. Reid, 7.30 p.m.

Tues., Nov. 19.—WESTERN BRANCH: Engineering Laboratories, University Walk, Bristol, "Vibration: A Survey of Industrial Applications," J. P. den Hartog, 7 p.m.

Wed., Nov. 20.—N. EASTERN A.D. CENTRE: Chemistry Lecture Theatre, University, Leeds, "The Ability to Stop," H. Clements, 7.30 p.m.

Thurs., Nov. 21.—HYDRAULIC GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Instrumentation for the Measurement of Fluid Pressure," 6.45 p.m. ★EAST MIDLANDS GRADUATES SECTION: Room 104, College of Technology and Commerce, Leicester, "Some Problems in the Development of Turbo Machines," S. Soundranayagam, 7.15 p.m. ★WESTERN A.D. CENTRE: Fortes Restaurant, Bath, "Construction and Behaviour Characteristics of Tyres, including the Tubeless Types," G. R. Shearer, 6.45 p.m.

Fri., Nov. 22.—1, Birdcage Walk, Westminster, London, S.W.1, Technical Film Show, 6.45 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Nov. 21.—GENERAL MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "Pulp Density Measurement with Ultrasonics," J. K. Almond and A. R. Burkin, and also "Changes in Copper Solubility during Flotation of Malachite: 2, Chemical Reactions during Conditioning and their Effect on Flotation," E. J. Pryor, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 15.—SWANSEA SECTION: Central Library, Alexandra Road, Swansea, "Master and Man," E. C. Gordon England, 7.30 p.m.

Mon., Nov. 18.—SHEFFIELD SECTION: Batchelors Peas, Ltd., Wadsley Bridge Sheffield 6, "Quality Control," 6.30 p.m. ★COVENTRY SECTION: The Craven Arms, High Street, Coventry, "Modern Gear Hobbing Practice," 7.15 p.m. ★STOKE-ON-TRENT SECTION: Grand Hotel, Hanley, Stoke-on-Trent, "Ferrous Die-Casting," C. A. Payne, 7.30 p.m.

Tues., Nov. 19.—PETERBOROUGH SECTION: Peterborough Technical College, Eastfield Road, Peterborough, "Need for Training of Technologists and Technicians," C. Grad, 7.30 p.m. ★TEES-SIDE SECTION: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "The Work of the Factory Inspector," S. E. Boxer, 7 p.m.

Wed., Nov. 20.—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Some Aspects of Technical Education in the U.S.A.," T. B. Worth, 7 p.m. ★WOLVERHAMPTON GRADUATE SECTION: Wolverhampton and Staffs College of Technology, Wulfruna Street, Wolverhampton, "Broaching and Broaching Techniques," A. E. Randall, 7.30 p.m.

Thurs., Nov. 21.—NORTHERN IRELAND SECTION: Kensington Hotel, Belfast, "Hydraulic Operation of Machine Tools," H. C. Town, 7.30 p.m. ★GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Manufacture of Small Metal Pressings," H. W. Townsend, 7.30 p.m.

Fri., Nov. 22.—WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "Recent Developments in the Control of Dust," W. B. Lawrie, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Mon., Nov. 18.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, "The Forth Bridge," J. K. Anderson, 5.55 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 15.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Some Aspects of Town Gas Distribution," J. E. Gray, 7 p.m.

Fri., Nov. 22.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Blowing of Blast-Furnaces," W. K. V. Gale, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 15.—Engineers' Club, Albert Square, Manchester, "The Runcorn-Widnes Bridge," J. Kenneth Anderson, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 15.—Mining Institute, Newcastle upon Tyne, "The Standardisation of Large Tankers," N. Carter, 6.15 p.m.

PLASTICS INSTITUTE

Tues., Nov. 19.—Wellcome Building, 183–193, Euston Road, London, N.W.1, "The Flow Properties of Polythene and their Effect on Fabrication," P. L. Clegg, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Nov. 19.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "The Supersonic Wind Tunnel," W. F. Hilton, 7 p.m.

Thurs., Nov. 21.—GUIDED FLIGHT SECTION: Royal Institution, Albemarle Street, London, W.1, Inaugural Lecture, "Guided Weapons and Aircraft: Some Differences in Design and Development," J. E. Serby, 6 p.m.

ROYAL STATISTICAL SOCIETY

Wed., Nov. 20.—INAUGURAL ADDRESS: London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, "Recent Developments in Economic Statistics," Sir Harry Campion, 5.15 p.m.

Thurs., Nov. 21.—BRISTOL GROUP: University of Bristol, Bristol 8, "Computing Methods for Optimisation Problems arising in Production Planning," C. M. Berners-Lee, 5.45 p.m.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Nov. 19.—B.I.S.R.A., Hoyle Street, Sheffield, "The Production and Properties of Cemented Carbides and Ceramic-Metal Combinations," E. M. Trent, 7 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Wed., Nov. 20.—CORROSION GROUP: 14, Belgrave Square, London, S.W.1, "The Protection of Magnesium Alloys," W. F. Higgins, 6.30 p.m.

Thurs., Nov. 21.—ROAD AND BUILDING MATERIALS GROUP: 14, Belgrave Square, London, S.W.1, "Producer-Gas Fired Lime Kilns," B. J. Gee, 6 p.m.

SOUTH WALES INSTITUTE OF ENGINEERS

Thurs., Nov. 21.—Institute Buildings, Park Place, Cardiff, "Hydraulic Drive: The Modern Transmission," R. H. Feu, 6 p.m.

UNIVERSITY OF LONDON KING'S COLLEGE

Thurs., Nov. 21.—Department of Civil Engineering, King's College, Strand, London, W.C.2, "The Development of Power in the Service of Man," C. K. Haswell, 5.30 p.m.

Advanced Engineering Courses

Operational Research. UNIVERSITY OF BIRMINGHAM. Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. Residential executive course, Monday, November 25, to Friday, December 6. Fee £50.